Re-evaluation of the Coal Resources of Western Cape Breton Island

P.A. Hacquebard,
K.S. Gillis and
D.S. Bromley

Paper 89-3

Nova Scotia

Department of Mines and Energy

Jack MacIsaac
Minister

John J. Laffin, P.Eng., FEIC
Deputy Minister

Halifax, Nova Scotia
1989

90-01109/

P. A. Hacquebard
Geological Survey of Canada
Atlantic Geoscience Centre
Bedford Institute of Oceanography
Dartmouth, Nova Scotia
B2Y 4A2

K. S. Gillis
Nova Scotia Department of Mines and Energy
32 Bridge Street
Stellarton, Nova Scotia
B0K 1S0

D. S. Bromley
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario
K1A 0E8

TABLE OF CONTENTS

	Page
ABSTRACT	1
BACKGROUND	
Introduction	3
Marine Seismic Surveys	
Coal Exploration Surveys on the West Coast of Cape Breton Island	3
Seismic Data Acquisition and Processing, 1978 and 1985 Surveys	7
Stratigraphy of the Coal Measures	8
Coal Resource Classification	8
RIVERSDALE COALS	
Tectonic Setting and Depositional Milieu of the Riverdale Group in Western Cape Breton Island	9
The Port Hood Coalfield	
Geological Setting	10
Mining History	12
Structure	12
Offshore Seismic Survey	16
Port Hood Coal Resources	17
The St. Rose-Chimney Corner Coalfield	
Geological Setting	17
Mining History	19
Structure	22
St. Rose-Chimney Corner Coal Resources	28
PICTOU COALS	
The Gulf of St. Lawrence Carboniferous Basin	28
The Mabou Coalfield	
Onshore Coal Data	29
The Mabou-Inverness Connection	33
Structure and Coal Resources at Mabou Mines	33
Offshore Seismic Survey	35
The Inverness Coalfield	
Onshore Coal Data	37
Structure and Coal Resources at Inverness	38
Offshore Seismic Survey	40
CONCLUSIONS AND RECOMMENDATIONS	41
ACKNOWLEDGMENTS	43
REFERENCES	43
LIST OF FIGURES	
Figure 1. Location map of west coast Cape Breton coalfields	4
Figure 2. Location map of marine geophysical surveys	5

Figure 3. Marine seismic streamer 6

Figure 4. Port Hood coalfield showing seam locations and structure contours on horizon 1 11

Figure 5. Correlations of the 6 Foot seam in holes PH-2 and PH-3 13

Figure 6. Diagrammatic geological cross section line B01.2-B01.3 14

Figure 7. Port Hood survey line B01.2-B01.3 15

Figure 8. Coal resource areas of the Port Hood coalfield 18

Figure 9. St. Rose-Chimney Corner coalfield showing seam locations and structure contours on No. 5 seam at St. Rose 20

Figure 10. Correlation of the St. Rose and Chimney Corner coal seams (after Bell, 1943) 21

Figure 11. Coal resource areas of the No. 5 seam at St. Rose 23

Figure 12. Cross-section through holes SR-4, SR-5 and SR-1, St. Rose (after MacNeil, 1985) 24

Figure 13. Cross-section through holes BH.2, SR-7A, -3, -1, -2, -6 and No. 2804, St. Rose (after MacNeil, 1985) 25

Figure 14. Cross-section through holes CC-4, -3 and -1, Chimney Corner (after Gillis, 1975b) 26

Figure 15. Cross-section between holes CC-2 and CC-3, Chimney Corner (after Gillis, 1975b) 27

Figure 16. Onshore 'Pictou' coal occurrences of the Gulf of St. Lawrence and Sydney Carboniferous basins (after Hacquebard, 1986) 29

Figure 17. Distribution and correlation of the main coal-bearing strata in the Gulf of St. Lawrence and Sydney basins (after Hacquebard, 1986) 30

Figure 18. Geological map of Mabou coalfield (after Hacquebard *et al.*, 1978) 31

Figure 19. Structure contours of the '7 Foot Seam of Inverness Equivalent' in the Mabou Mines area (CDEF is coal resource block, after Hacquebard, 1986) 32

Figure 20. Correlation of the Mabou-Inverness coal-bearing sequence (after Hacquebard, 1986) 34

Figure 21. Mabou survey line 6 36

Figure 22. Diagrammatic geological cross section, line 6 38

Figure 23. Geological map of Inverness coalfield (after Gregory, 1978) ... 39

Figure 24. Structure contours on assumed 7 Foot seam horizon in the Inverness coalfield and adjacent area, based on 1985 seismic survey (LaPierre, 1986b; EFGH and IJKL are coal resource blocks, after Hacquebard, 1986) 40

Figure 25. Inverness survey line 4402-B04 and diagrammatic geological cross section 42

LIST OF TABLES

Table 1. Stratigraphic subdivisions and age of upper Paleozoic rocks in eastern Canada 9

Table 2. Coal resources on the 6 Foot seam, Port Hood coalfield 19

Table 3. Coal resources on the No. 5 seam at St. Rose 28

ABSTRACT

In Western Cape Breton Island, on the eastern side of the Gulf of the St. Lawrence Carboniferous Basin, four coalfields extend 55 km along the coast from Port Hood northeast to Chimney Corner. They are the Port Hood, Mabou, Inverness and St. Rose-Chimney Corner coalfields. The coalfields developed in local depocenters within a wide intracontinental transform fault zone. Movement on the faults was dominantly right-lateral strike slip and led to the development of folds and faults within the coalfields.

Each coalfield has supported small intermittent mining operations but only the St. Rose-Chimney Corner field is producing now. Due to the small land area present at each locality (10 - 25 km^2) most of the mining was submarine. The exception is at St. Rose where a small landlocked basin, 2.4 km^2 in area, is part of the St. Rose-Chimney Corner coalfield. The mined seams within the coalfields ranged from 1.5 to 3.7 m thick.

The Port Hood and St. Rose-Chimney Corner coalfields belong to the Westphalian A Riversdale Group whereas the Mabou and Inverness fields are in the younger Pictou Group and are Westphalian C and D age respectively. The latter coalfields form part of a large coal basin that underlies the Gulf of St. Lawrence and is delineated by the occurrence of coals of the same age in five offshore wells. The coal rank is high volatile B and C bituminous with average ash and sulphur contents of 10% and 5% respectively and a calorific value of 27.9 Mj/kg (12,000 Btu/lb).

Drilling programs in 1975, 1978, 1979 and 1984 and seismic surveys in 1966, 1977, 1978 and 1985 have delineated both onshore and offshore coal resources. The structure of the coalfields and the position of the coal seams have been determined using marker horizons identified by the seismic surveys.

Drilling programs have provided stratigraphic information and quality data on the coal seams as well as confirmation of seismic interpretations. Total demonstrated and inferred coal resources indicate *in situ* tonnages of 22.4 million tonnes at Port Hood and 214 million tonnes at Inverness. Speculative coal resources of 113 million tonnes have been outlined at Mabou while measured coal resources of 3.4 million tonnes are present at St. Rose.

BACKGROUND

INTRODUCTION

Coal mining operations on western Cape Breton Island have been carried out in four coalfields that extend 55 km along the west coast of Cape Breton Island. From south to north, the coalfields are: Port Hood, Mabou, Inverness and St. Rose-Chimney Corner (Fig. 1). All occupy small land areas (2.5 - 10 km^2) and most mining has been submarine.

Mining began in 1865 and, with the exception of the small operation at St. Rose, ceased in 1966. During this period 9 million tonnes were produced (Gregory, 1978) and the current average annual production of St. Rose is 50,000 tonnes. The coals are high volatile B and C bituminous with average ash and sulphur contents of 10% and 5% respectively and a heat value of 27.9 Mj/kg (12,000 Btu/lb). Mined seams ranged from 1.5-3.7 m thick.

The submarine resources of the Inverness County coalfields have long been a matter of much speculation and it was not until the drilling and seismic work done in the mid and late 1970s that more abundant and reliable data became available. A further update was possible in 1986 when the results of the offshore seismic surveys at Port Hood and Inverness were added. The present calculation gives a total of 353 million tonnes of demonstrated, inferred and speculative coal resources in the four fields under discussion.

Results from the recent drilling and seismic surveys which were carried out as part of the coal inventory program of the Nova Scotia Department of Mines and Energy (NSDME), are described in this report. The new data complement earlier work in determining structural and coal resource evaluations of the individual coalfields.

MARINE SEISMIC SURVEYS

Coal Exploration Surveys off the West Coast of Cape Breton Island

Marine seismic studies have been conducted off the west coast of Cape Breton Island, Nova Scotia since the early 1960s. Marine geophysical techniques have proven to be a very valuable tool in helping to appraise coal resource potentials.

Early attempts of interpretation of dipping strata in the Northumberland Strait were made possible by information derived from a single seismic profile taken from a shallow sparker survey carried out in 1966 by the Bedford Institute of Oceanography (Kranck, 1971; Hacquebard 1986). Further shallow penetration surveys were conducted in 1977 by the Nova Scotia Research Foundation (MacKay, 1977) which collected approximately 70 line-km of shallow seismic data in the offshore area near the Mabou coalfield (Fig. 2). In this survey a small sparker sound source and analog recording techniques were used to outline shallow bedrock structure and identify the apparent dip of the near-seabed rock layers (MacKay, 1977). Deeper seismic penetration was necessary to identify regional structure and aid in the selection of potential drilling sites. This prompted NSDME to undertake the first of three recommended deep penetration seismic surveys.

Nova Scotia Department of Mines and Energy contracted Geomarine Associates Limited to collect approximately 200 line-km of seismic profiles. The profiles were gathered in June and July, 1978 over a 10 km x 15 km grid between Sight Point and Colindale (Fig. 2). After processing of the survey data, the seismic profiles were used to assist in the selection of two test drilling sites (M-1 and M-2A, Fig. 2). Based on the results of the Mabou survey, NSDME and

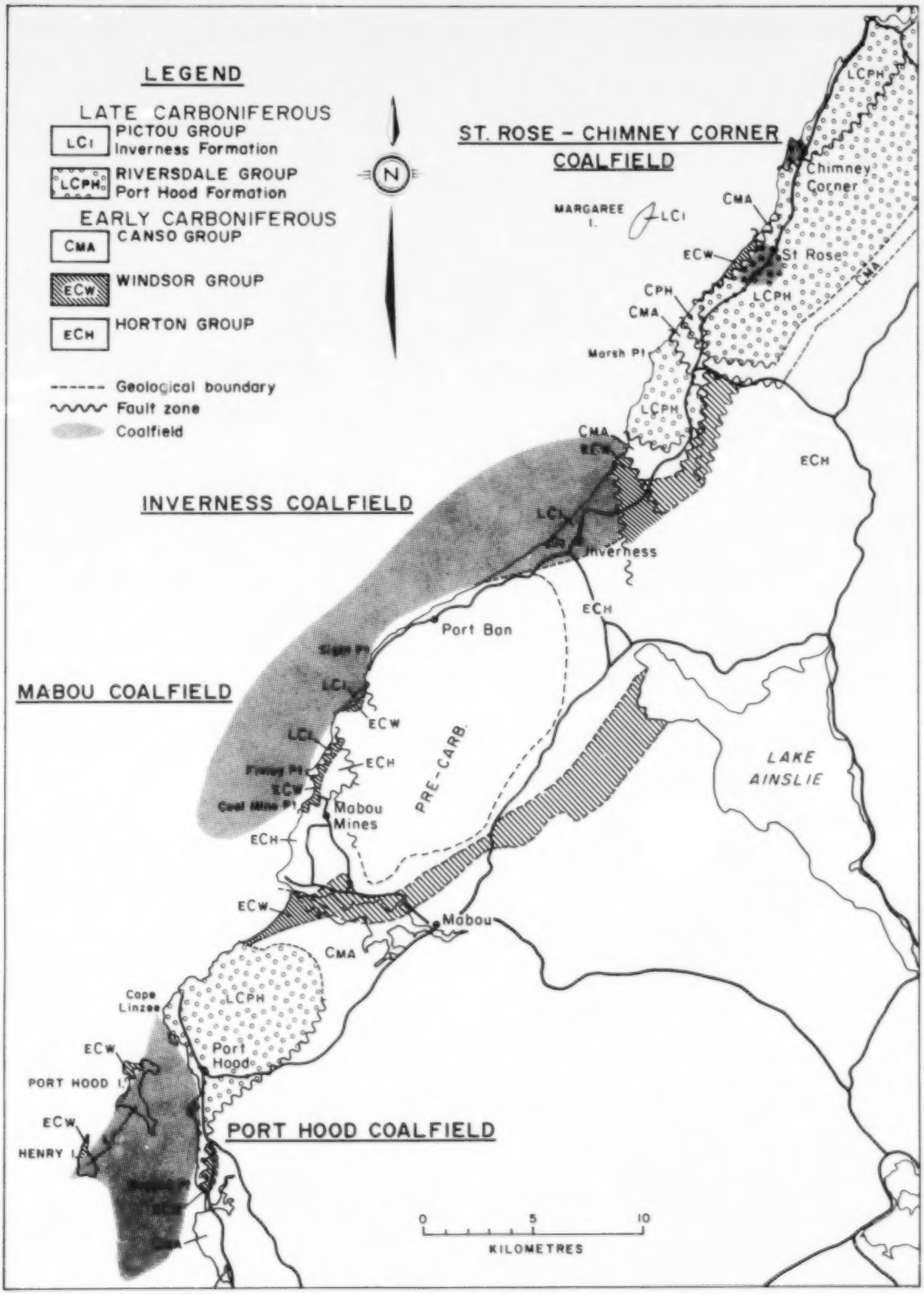


Figure 1. Location map of west coast Cape Breton coalfields.

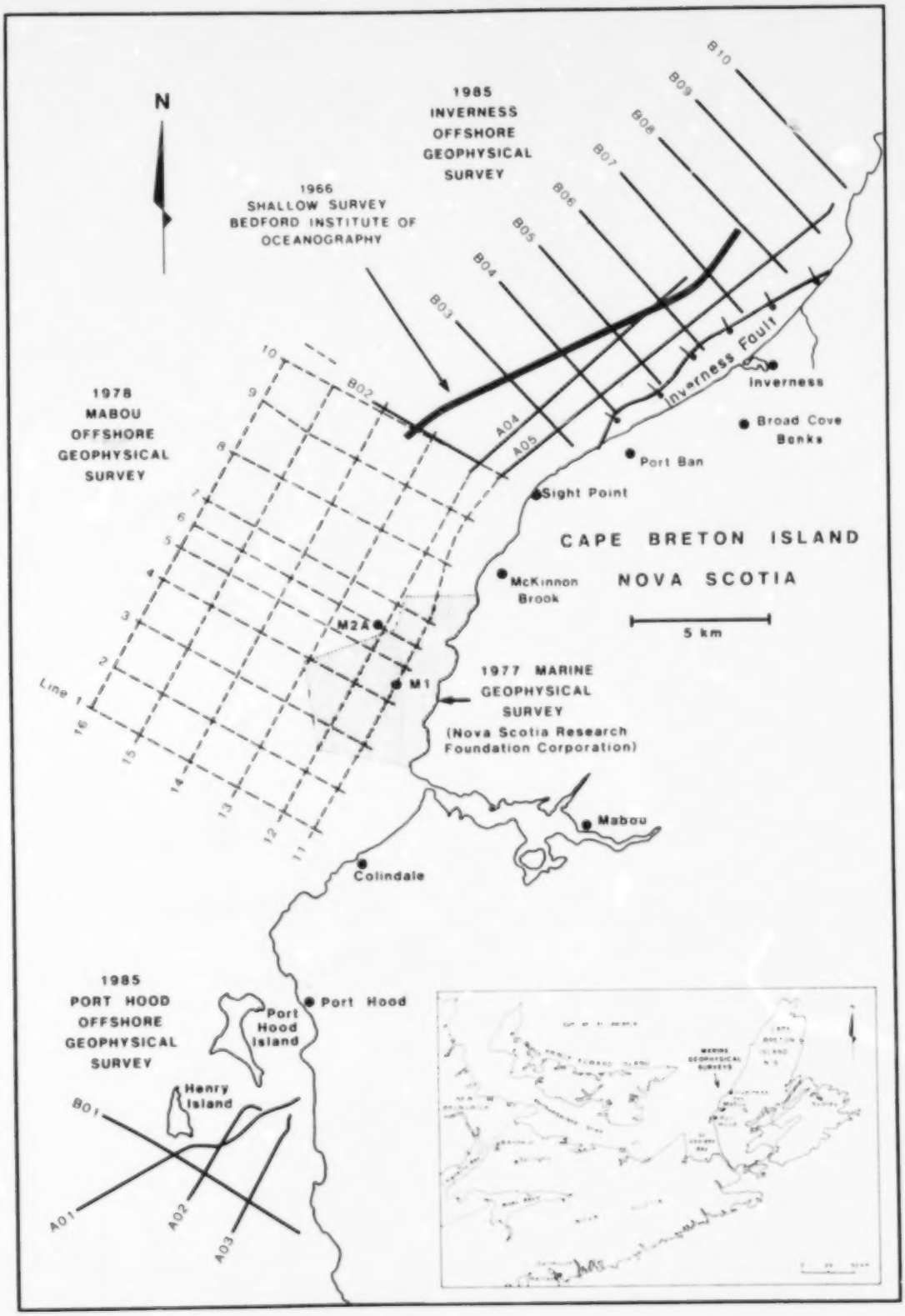


Figure 2. Location map of marine geophysical surveys.

the Atlantic Geoscience Centre (AGC) suggested that future seismic surveys would be beneficial in defining the northeastern limit of the Mabou coalfield. Two further marine seismic surveys were carried out in 1985 under the Canada - Nova Scotia Mineral Development Agreement.

The first 1985 survey located near Port Hood and Henry Islands was contracted out to McGregor Geoscience Limited. The main aims of this investigation were to establish the structural geology offshore at Port Hood and provide control for projecting the depth of the 6 Foot coal seam offshore (Bromley and Hunter, 1986). Approximately 25 line-km of data were collected in September, 1985 (Fig. 2). Although direct correlation of coal seams to seismic events is not possible without further drillhole control, a projected depth for the 6 Foot seam of 1100 ± 110 m below the centre of Henry Island (LaPierre, 1986a) was made by extrapolation based on the offshore structural data.

McGregor Geoscience conducted a second marine survey in September, 1985 on behalf of the Geological Survey of Canada (GSC) and NSDME. The main objective again was to establish structural information offshore Inverness which would provide control for projecting the depths of the 7 and 13 Foot coal seams offshore beyond the Inverness fault (LaPierre, 1986b). The 84 km of seismic lines were run in a grid pattern similar to the 1978 survey (Fig. 2). One of the constraining factors of the data is the lack of seismic coverage over the Inverness thrust fault. This fault closely parallels the coastline in the shallow water (5-15 m). Since only two of the seismic lines (B04 and B06) show

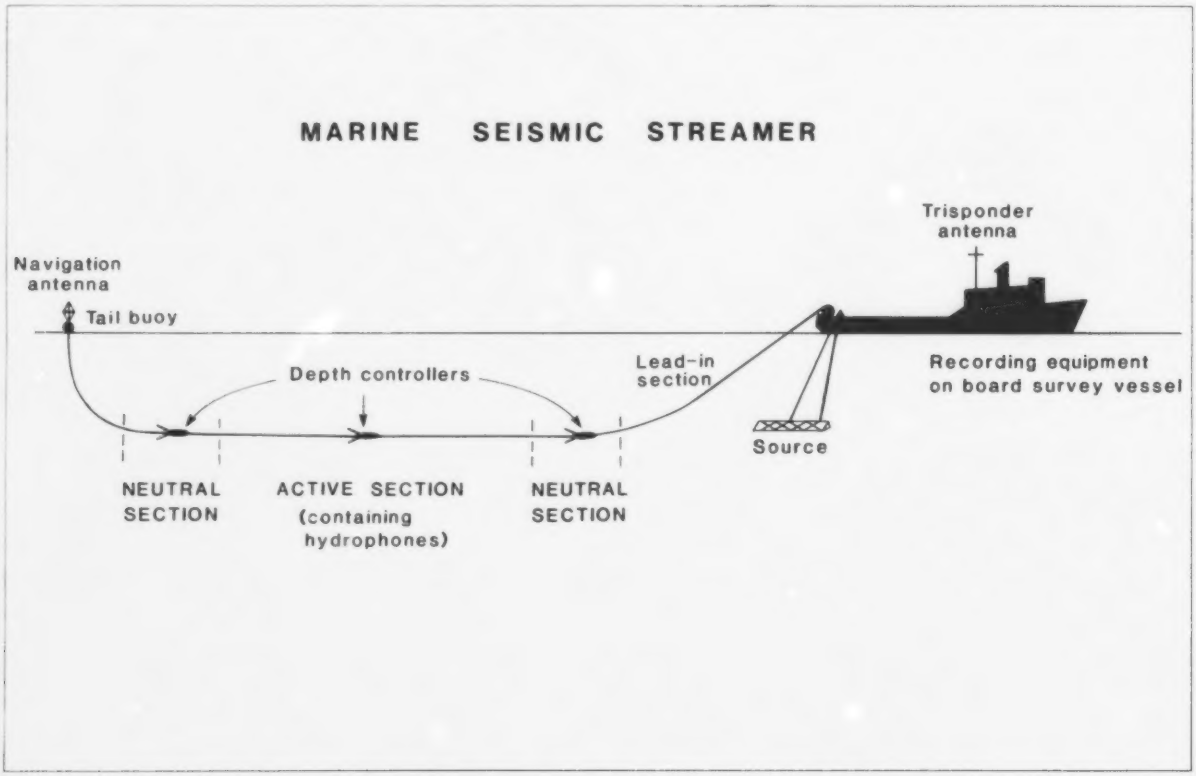


Figure 3. Marine seismic streamer.

evidence of intersecting the Inverness Fault, correlation of known coal seams across this fault remains speculative. An extrapolation was made possible across the Inverness Fault by combining the observed data with information from a horizontal borehole (BH-884) drilled through this fault plane. A vertical displacement of 52 m was calculated across the fault and an average dip of 11° northwest was calculated for the Inverness coal seams (LaPierre, 1986b).

Seismic Data Acquisition and Processing, 1978 and 1985 Surveys

Seismic reflection data were acquired using a multichannel system. Acoustic energy (in the range of 30-250 Hz) generated by the source is reflected off subsurface structure and is recorded by one of the hydrophone groups (channels) in the streamer. The streamer (Fig. 3) is towed at a pre-set depth a few metres below the sea surface and is maintained at this depth by pressure-sensitive cable levelling devices. Neutral sections at both ends of the streamer are necessary to reduce towing noise on the hydrophones. The source is fired with a repetition rate such that a constant distance is maintained between each shot. This is necessary to perform Common Depth Point (CDP) processing after data acquisition. Such processing serves to enhance the signal-to-noise ratio of reflected events.

Reflections are observed from rock structure wherever velocity or density variations occur at a lithological boundary. Many subtle velocity-density boundaries can be observed with the reflection method. Frequently the occurrence of coal seams can result in large amplitude reflection events because of the pronounced velocity and density difference between coal and the surrounding sedimentary rock (Harmon and Rutter, 1979).

The seismic data acquired by the streamer are amplified, digitized, and recorded aboard ship using a multichannel seismograph. To achieve sufficient high frequency resolution, data are digitized at a 1 millisecond sample rate over a period of 2 seconds a shot.

For the 1978 Mabou survey a 12-channel streamer consisting of eight hydrophones summed together per channel and a group spacing of 8.33 m were used. The source consisted of a Flexichoc FHC-50 electro-mechanical implosive device. The data were recorded using a Sercel SN-338 B seismograph. The MV Snowflake, an inshore fishing vessel, was used for daylight operations for the survey. The shallow draft of the vessel (1.2 m) allowed the survey lines to be brought close to shore.

The 1985 surveys used a 24-channel streamer with 15 hydrophones per group and a 16.7 m spacing between groups. The source was a 16 kilojoule, 9 element sparker towed at a depth of 3 m. Shots were fired at 16.7 m intervals to provide 12-fold CDP coverage. Recording during the 1985 surveys was done using the Geomechanique (IFP) HR 6300 seismograph system with a 1 millisecond sample rate for 2 seconds of data. The MV Brandal (draft of 6.3 m) operated on a 24-hour basis for these surveys. The all-weather capability of this vessel was selected at the expense of many shallow water operations nearshore at Inverness.

The Del Notre Trisponder navigation system, with three shore stations giving positioning accuracy in the order of 3 m, was used for all surveys.

To obtain additional high-resolution data of near-seabottom structure a single-channel mini-streamer positioned near the source recorded high frequency, subbottom reflections. Side-scan and echo-sounder systems which provide

additional data on bedrock exposures and seabottom morphology were employed for the 1985 surveys.

Processing of multichannel digital data was done under contract by Calgary-based processing companies. Standard processing procedures were followed, including demultiplexing, digital filtering dereverberation, deconvolution velocity analysis and common depth point summation. Processing costs were approximately 15% of acquisition costs, bringing the total cost per line-km to approximately $1250/km (1985) dollars.

STRATIGRAPHY OF THE COAL MEASURES

The stratigraphy of the Carboniferous in Eastern Canada is shown in Table 1. The oldest coal occurs in the nonmarine Horton Group, where there are a few isolated, noncommercial seams. Coal formation was interrupted with the deposition of the marine Windsor sediments and began again with the start of the long period of continental conditions of the Upper Carboniferous. Coal formation became more widespread as time progressed.

Coal of mineable thickness, but still on a limited scale, occurs in the Riversdale Group in the coalfields of Port Hood and St. Rose-Chimney Corner. On the basis of the contained fossil flora (Bell, 1938) and the miospore assemblage (Hacquebard, 1972), a Westphalian A age is indicated for these deposits. More productive coal formation occurred during deposition of the Cumberland Group in the coalfields of Joggins-River Hebert and Springhill on mainland Nova Scotia. They are Westphalian B and are not present on Cape Breton Island. The most extensive coal is in the Pictou Group and is Westphalian C, D and Stephanian. The coals of Mabou, Inverness, Sydney, Pictou (on mainland Nova Scotia) and New Brunswick are all of this age.

Five spore zones (A to E in Table 1) have been recognized in the Pictou Group and permit precise correlations between isolated coal occurrences (Barss and Hacquebard, 1969; Hacquebard, 1986).

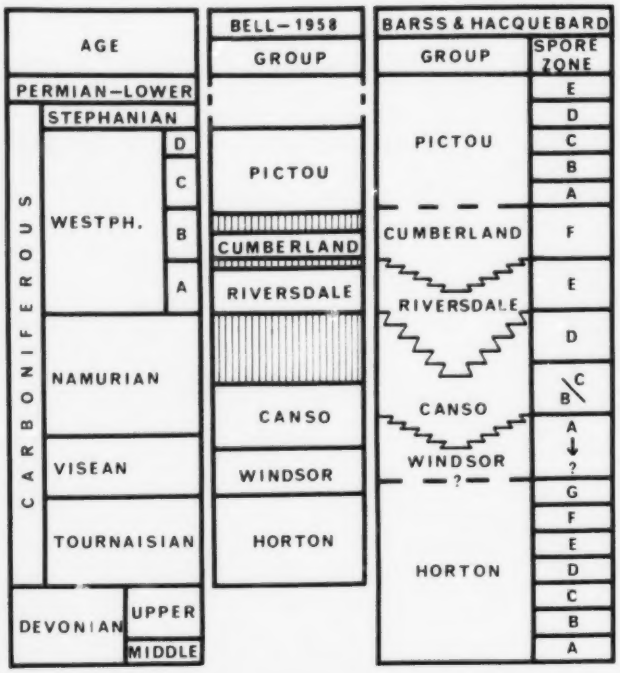
COAL RESOURCE CLASSIFICATION

Coal resources refer to total *in situ* coal that is contained in seams occurring within specified limits of thickness, depth and distance from known points of observation and are classified according to two considerations, assurance of existence and feasibility of exploitation (Bielenstein et al., 1979). The assurance of existence of a coal deposit is defined by the terms "measured", "indicated", "inferred" and "speculative". They are used to denote levels of confidence based on defined parameters that have been assigned to each category. "Demonstrated" means "measured" plus "indicated" coal resources. The feasibility of exploitation of a coal deposit is subdivided into resources of immediate interest and resources of future interest.

In Nova Scotia, resources of immediate interest are coal seams that, due to favourable thickness, quality, depth and location are amenable to exploration or exploitation. In onshore areas coal seams 0.5 m thick to a depth of 45 m and all seams 1 m thick to a depth of 1200 m are in this category. In offshore areas, seams 1 m thick to a depth of 1200 m are included. Measured and indicated resources of immediate interest must first be established in a coalfield before they can be considered mineable.

Resources of future interest include the same criteria set out for resources of immediate interest except that the parameters of thickness, quality, depth and location are less favourable and thus, the coals are not of immediate interest but may become of interest in the future.

Table 1. Stratigraphic subdivisions and age of Upper Paleozoic Rocks in eastern Canada (Hacquebard, 1972).



RIVERSDALE COALS

TECTONIC SETTING AND DEPOSITIONAL MILIEU OF THE RIVERSDALE GROUP IN WESTERN CAPE BRETON ISLAND

In Nova Scotia, the Riversdale Group overlies the Canso Group and underlies the Cumberland Group or younger strata. The upper and lower contacts are generally disconformable, although locally they may be unconformable (Bell, 1944).

The Riversdale Group is entirely terrestrial and dominantly fluvial in origin (Bell, 1944; Gersib and McCabe, 1981) and comprises fine- to coarse-grained red and grey sandstone, siltstone, mudstone and locally conglomerate near the base. Several workable coal seams are locally significant. Faunal and floral assemblages of the Riversdale Group indicate that it is not older than late Namurian nor younger than Westphalian A. An early Westphalian A age is considered most probable (Bell, 1944).

Sediments of Carboniferous age in the Maritimes were deposited in a broad subsiding basin (Fundy Basin of Belt, 1968). Within the basin tectonism was diachronous and variable and resulted in the formation of a complex series of interconnected basins (Bradley, 1982). Deposition in the partially fault-controlled subbasins was consequently variable and complex.

Initially, fault-bounded basins developed in response to extensions within a regional strike slip system (Bradley, 1982). In the early stages, sedimentation was controlled by high angle faults and facies ranged from fanglomerates to lacustrine deposits. As the area of subsidence increased, fault control of deposition decreased, fluviolacustrine conditions prevailed and the influence of local uplift on sedimentation faded (Bradley, 1982).

In western Cape Breton, uplift is evidenced by the massive and coarse arkosic to feldspathic sandstone, which suggests rejuvenated source areas (Kelley, 1967) at the base of the Riversdale Group. This is in contrast with the underlying Canso Group strata which consist of fine clastics indicative of fluviolacustrine deposition in a semi-arid climate (Howie and Barss, 1975).

The warping character of the uplift in western Cape Breton was not intense and no folding of the strata has been observed (Bell, 1944; Howie and Barss, 1975; Currie, 1977). Sedimentation proceeded from a lower sequence consisting of fluvial channel sandstone and interbedded red overbank mudrock to an upper sequence of cross-bedded grey sandstone and predominantly grey mudstone with associated coal seams and minor red beds.

The presence of grey mudstone, abundant plant debris and coal seams indicates a fluviolacustrine to swamp depositional environment. No marine fossils have been found in the Riversdale Group (Howie and Barss, 1975; Gersib and McCabe, 1981).

THE PORT HOOD COALFIELD

Geological Setting

The Port Hood coalfield is situated near the village of Port Hood (Fig. 1). The coal measures occur in the Port Hood Formation and are exposed in a narrow belt extending 5 km northward along the coast from Little Judique Harbour to Black Point (Fig. 4).

The coalfield lies in the gently folded southwestward-plunging Port Hood syncline (Norman, 1935; Haites, 1952). It is bounded on the west by the Port Hood fault which brings Windsor Group rocks into contact with Riversdale strata. The field is truncated to the southeast by the Ragged Point fault. Inland and to the east the Port Hood Formation is in conformable contact with the underlying Canso Group (Belt, 1965). Strata of the Inverness Formation (Pictou Group) overlie the Port Hood Formation and are exposed on Port Hood and Henry Islands. The contact between the formations is not exposed but evidence from drill- holes on Port Hood Island indicates that the two are structurally concordant.

The Port Hood Formation was divided by Norman (1935) into two lithological units. The lower 885 m consists of massive grey sandstone with interbedded red mudstone. The upper 395 m comprises fluvial sandstone and grey arenaceous mudstone with minor carbonaceous mudstone and coal seams. Paleocurrent measurements indicate that the sediment supply for the Port Hood Formation was derived from the west (Gersib and McCabe, 1981).

Gersib and McCabe (1981) described the coal-bearing section of the formation that is present on the shore at Port Hood. Their work indicates that the depositional environment of the Port Hood Formation in this locality was terrestrial with a meandering river system dissecting a swampy floodplain. The lack of marine fauna supports an alluvial plain setting.

Four coal seams are present at Port Hood but only one, the 6 Foot seam, was of mineable thickness (Fig. 4). This seam was approximately 2 m thick with a 16 cm clay parting that thinned in a down-dip direction. The seam outcropped on the shore at Port Hood but the coal has been extracted and is no longer exposed. It dips 20° westward from Port Hood but decreases to 15° as indicated by the position of the 6 Foot seam in hole PH-3 on Port Hood Island.

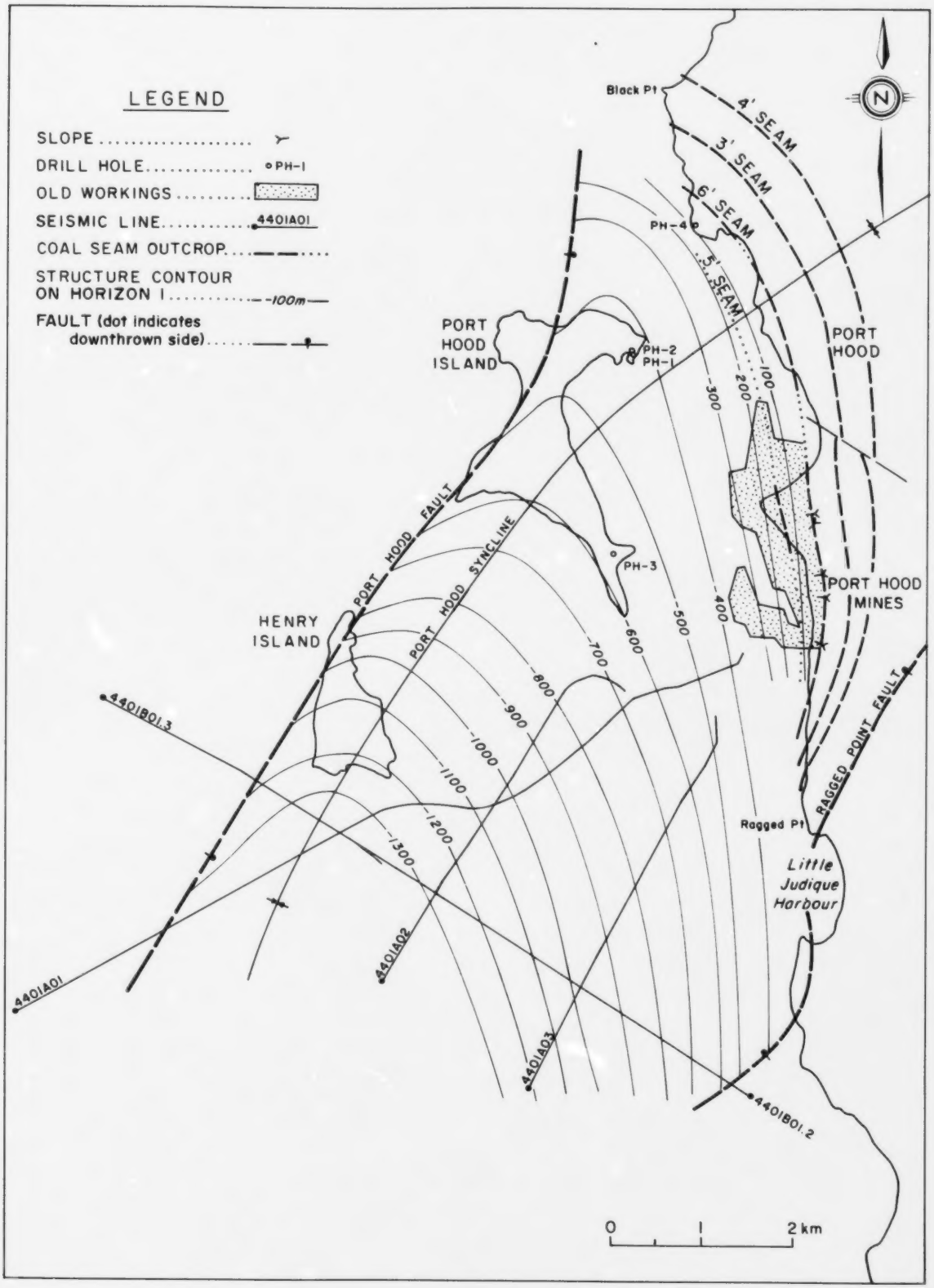


Figure 4. Port Hood coalfield showing seam locations and structure contours on horizon 1.

Mining History

Mining of the 6 Foot seam began in 1865 and continued intermittently until 1966. The original mine closed in 1911 when an influx of seawater along a fault forced the suspension of operations. Attempts to dewater in 1947 were unsuccessful. Analyses of the mine water taken at that time indicated a salt content of more than twice that of normal seawater and it was concluded that the water entering the workings must course over strata containing salt beds (Grant, 1947). This lends credence to the interpretation of Leonard (1951) that structural complexities in this area are due to diapiric movements.

A total of 1.3 million tonnes of high volatile B bituminous coal was produced from the 6 Foot seam. Proximate analyses, based on seven coal samples reported from the old mines and samples from two drillholes indicate on an "as received" basis the following: moisture 4.8%; ash, 14.7%; volatile matter, 34.4%; fixed carbon, 46.1% with sulphur at 7.7% and a calorific value on an "as received" basis of 26.3 Mj/kg (11303 Btu/lb).

Structure

Since the turn of the century, several drilling programs have been conducted in the Port Hood area to delineate the geological structure and to investigate the mining potential of the Port Hood coalfield. The most recent was by the Nova Scotia Department of Mines in 1975 (Gillis, 1975a) and was designed to investigate the 6 Foot seam at depth. Two holes (PH-2 and PH-3) were drilled on Port Hood Island, both of which intersected the 6 Foot seam (Figs. 4 and 5). Hole PH-1 was abandoned at 131 m due to drilling difficulties. The 6 Foot seam was intersected in PH-2 at 452 m where it was 76 cm thick. This hole indicates a deterioration in seam thickness northward compared with the thickness recorded in the mines to the southeast that showed an average seam thickness of 160 cm. A similar northward deterioration of the 5 Foot seam overlying the 6 Foot seam was noted previously (Douglas, 1945).

Near the south end of Port Hood Island, hole PH-3 intersected what is considered to be the 6 Foot seam at a depth of 586 m. Based on geophysical logs, the seam thickness was 2.4 m. A second seam of coal 2.0 m thick was intersected at 594 m. The presence of the second coal seam is problematic. It is either a split of the 6 Foot seam or a coal seam not previously recognized on the mainland which has its maximum development offshore in the central part of the syncline. This seam may be represented in hole PH-2 by a black mudstone with coaly laminae and ironstone present at 459.7 m (Fig. 5). The drastic reduction required in stratigraphic separation from that recorded on the mainland would seem to preclude this second seam from being either the 6 Foot seam or one of the two seams underlying the 6 Foot seam.

Hole PH-4 was drilled at Port Hood and the 6 Foot seam was 60 cm thick at a depth of 80.2 m.

The drilling indicated the continuation of the 6 Foot seam under Port Hood Island and probably as far west as the Port Hood fault (Fig. 4). The southwestern margin of the basin remained undefined however, and as the coalfield is entirely submarine, save for Henry Island, a marine seismic survey was carried out in 1986 under the terms of the Canada - Nova Scotia Mineral Development Agreement to determine the structure of the basin and the nature of the bounding faults (LaPierre, 1986a).

The results of the seismic survey have further defined the structure of the Port Hood coalfield. Figure 6 shows a structural interpretation of the Port Hood syncline. The structure

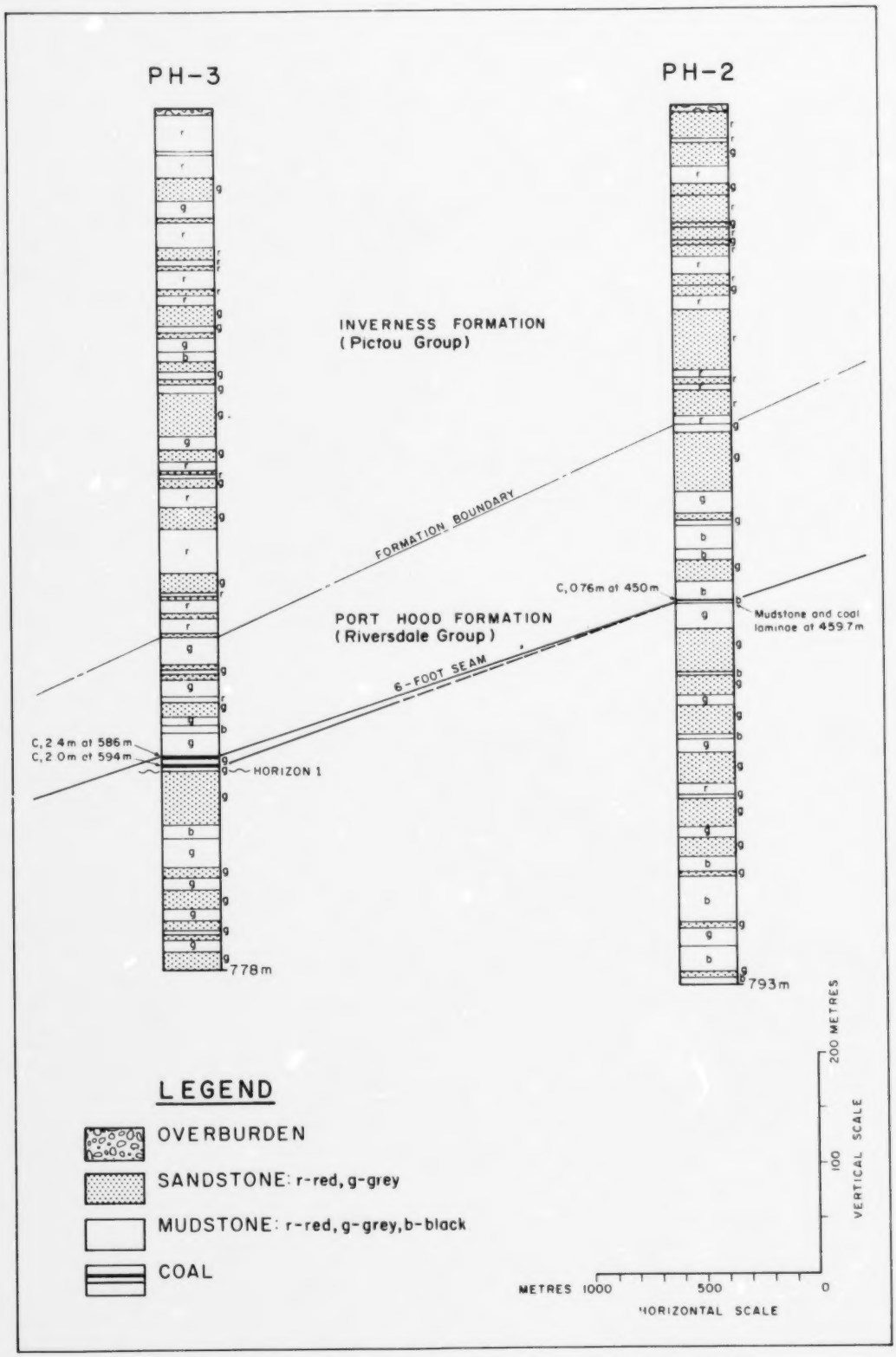


Figure 5. Correlations of the 6 Foot seam in holes PH-2 and PH-3.

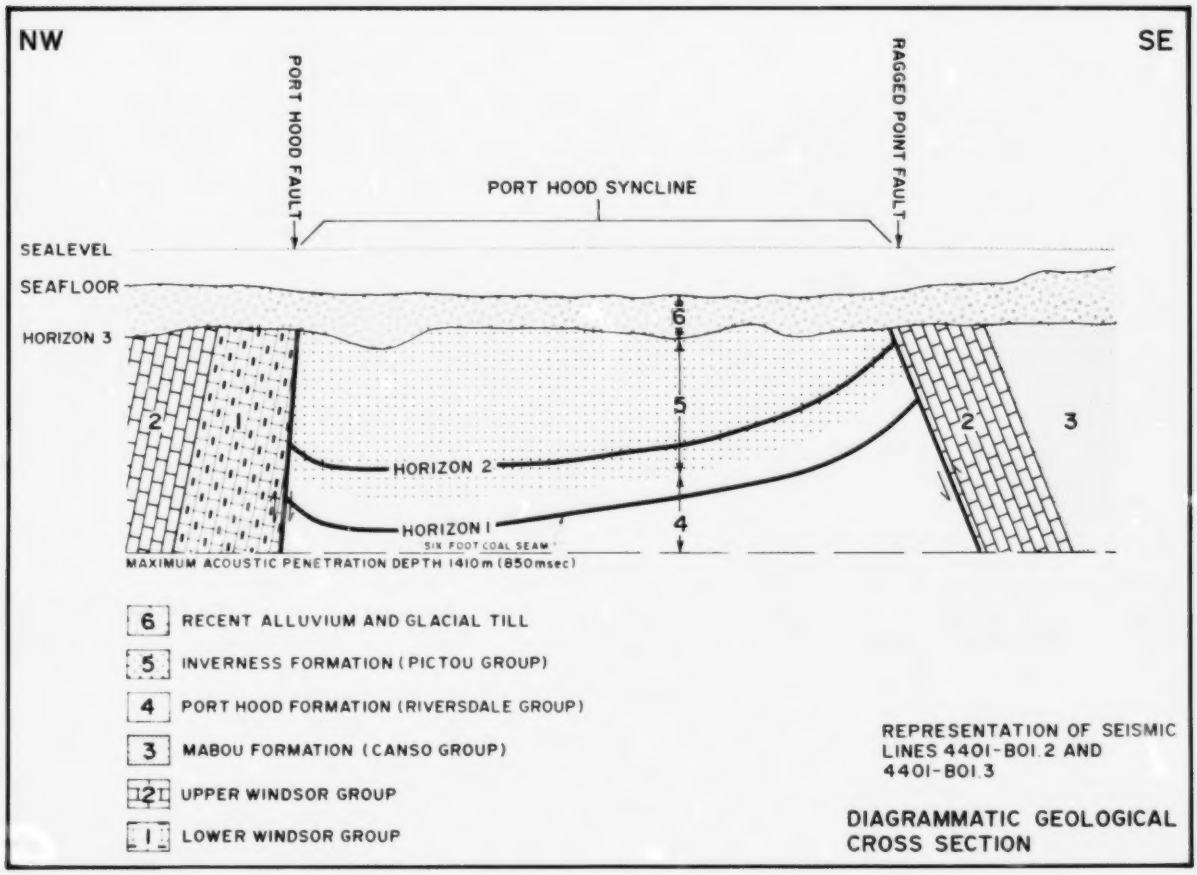


Figure 6. Diagrammatic geological cross section line B01.2-B01.3.

contours in Figure 4 represent Horizon 1, a seismic break that marks the top of a series of high to moderate amplitude reflectors (Fig. 7). The structural configuration indicated is based on integration of seismic data with data obtained from outcrops, mine workings and drillhole information. The closest lithological information to the strata covered by the seismic lines is that found in hole PH-3 near the southern end of Port Hood Island.

The lithology of hole PH-3 (Fig. 5) is interbedded red and grey sandstone and mudstone with coal seams. On the borehole section, Horizon 1 is in the vicinity of the contact between the grey and black mudstone unit containing the coal seams and the thick sandstone unit located at a depth of 600 m. The seismic reflectors that constitute Horizon 1 of Figures 6 and 7 appear to be in very close proximity to the position of the 6 Foot seam and are therefore used to determine the approximate position of that seam in the Port Hood syncline.

The western and southeastern sides of the syncline are truncated by the Port Hood and the Ragged Point faults. The trend of the Port Hood fault is projected from its known positions on the islands and from two seismic lines that cross the trace of this fault southwest of Henry Island. The fault is shown to be a high angle reverse fault that brings older Windsor Group strata in contact with the younger

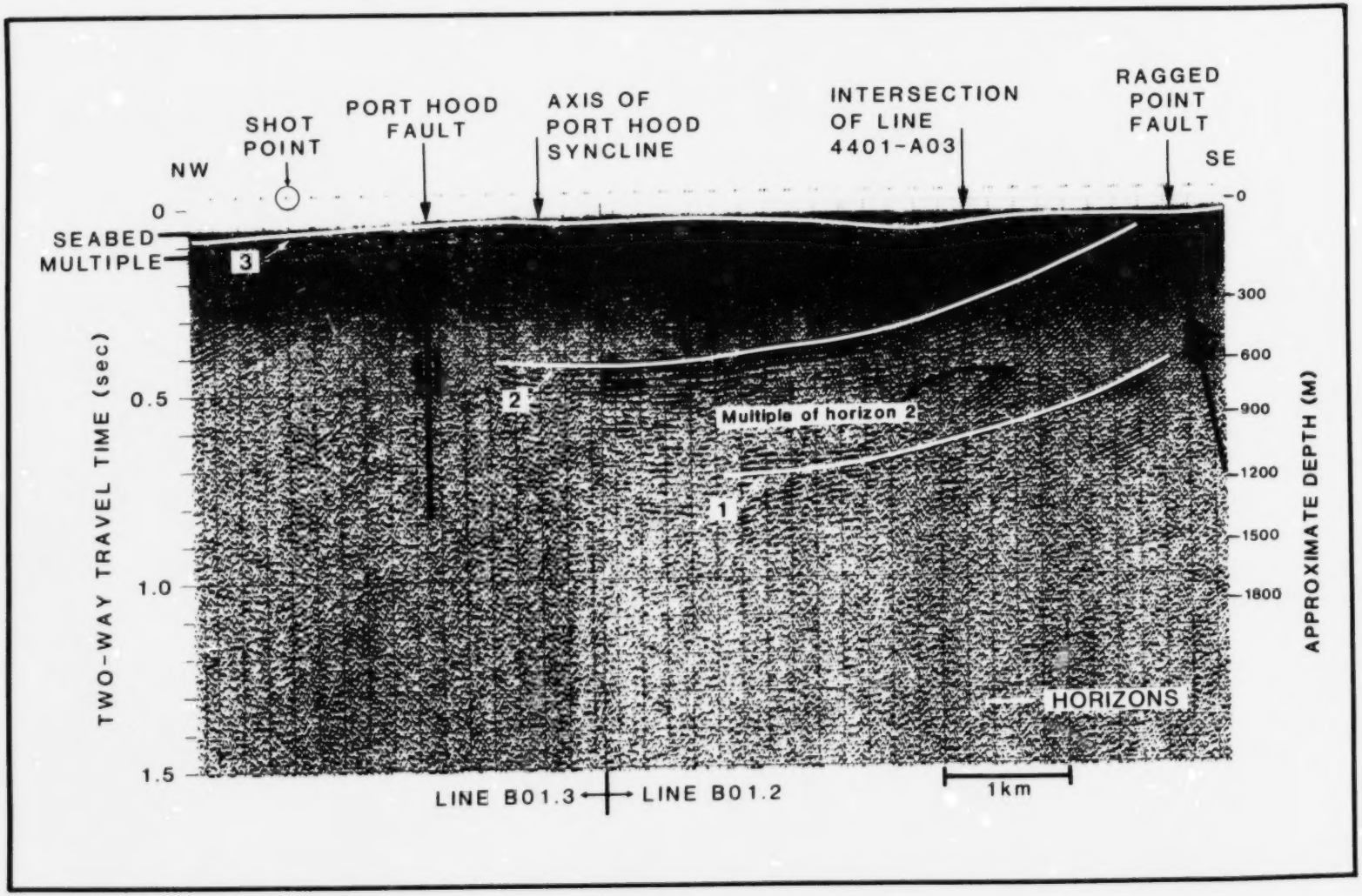


Figure 7. Port Hood survey line B01.2-B01.3.

Riversdale Group rocks. The Ragged Point fault is also a reverse fault which outcrops on the shoreline at Ragged Point where Windsor and vertical to overturned Riversdale strata are found juxtaposed. This corroborates other writers who stated that the faults paralleling the west coast are young landward thrusts (Webb, 1969) and that compression was in a northwest-southeast direction (Douglas, 1945; Webb, 1969). The origin of thrust faulting on western Cape Breton Island is still not fully understood (Currie, 1977). According to Hacquebard (1986) this faulting occurred in post Permian, probably early Triassic time, as is indicated by coal rank variations observed at Mabou Mines.

The fault indicated near the southeastern end of the seismic line 4401B01.2 (Fig. 7) is interpreted as the Ragged Point fault. This interpretation necessitates a rather sharp flexure of the fault to the southwest south of Little Judique Harbour. The indicated strike is 230° true. In this case, the fault would intersect the Port Hood fault approximately 10-12 km south-southwest of Henry Island and effectively limit the extension of the Port Hood coalfield to the southwest.

Offshore Seismic Survey

A discussion of the seismic results using one of the four lines as a specific working example will show how the seismic information has enhanced the overall understanding of the offshore geology.

Figure 6 shows a cross-sectional interpretation of the Port Hood syncline. This diagrammatical cross-section is based on multichannel seismic data taken from line B01 (Fig. 7). The important features evident on the seismic data are Horizons 1, 2 and 3 and two faulted areas labelled the Port Hood fault and the Ragged Point fault. A brief description of each of these events will show how the overall offshore structure has been interpreted.

The uppermost reflector, Horizon 3, represents the base of the Quaternary overburden. This unit, mapped by Kranck (1971), is composed mainly of recent alluvium and glacial till. The average thickness of overburden sediments is 20 m, although shore-parallel troughs up to 65 m deep can be observed on the seismic data (LaPierre, 1986a). Below Horizon 3 are the Carboniferous strata within the Port Hood syncline.

The Port Hood syncline is in faulted contact at both extremes of the section with older Windsor Group rocks (Figs. 6 and 7; LaPierre, 1986a). The two faults (Port Hood fault and Ragged Point fault) are drawn as distinct lines on the seismic profile but in fact they appear as "zones" of poor reflector continuity on the seismic data. It should be noted that the interpretation of these faults is not based only on seismic information.

Because only two of the seismic lines (B01.3 and A01) were extended over the Port Hood fault, its location was determined with the aid of onland information. The trend of the Port Hood fault was projected from its known positions on the island. This projection was then confirmed by observing the deteriorated quality of the seismic data at the proposed intersecting locations. Onland tracing of the Ragged Point fault is supported by seismic data. The intersection of the fault is seen near the southeastern portion of line B01 (Fig. 7). This fault zone is not easily discernable based solely on the seismic records.

The most shallow main reflector within the Carboniferous is Horizon 2 (Figs. 6 and 7). It is the most continuous reflector on the seismic section and extends almost

uninterrupted between the faulted extremes of the syncline. This event is believed to originate from within the Inverness Formation and is the first in a series of conformable reflectors that extend approximately 150 m below it (LaPierre, 1986a). The depth of Horizon 2 ranges from less than 100 m nearshore to over 600 m in the centre of the syncline.

The deepest and most prominent seismic event is Horizon 1 (Figs. 6 and 7). This reflector extends from approximately 400 m (400 msec) below sea level in the southeast to more than 1200 m (800 msec) below sea level. The horizon becomes less coherent with depth toward the northwest. Two possible causes for this signal deterioration are acoustic attenuation of the signal by the earth (LaPierre, 1986a) and possible interference from the multiple reverberation of Horizon 2. LaPierre (1986a) suggests that this horizon may originate from within the Port Hood Formation, although a hiatal unconformity between the Inverness and Port Hood Formations could not be positively identified on the seismic records.

A structural contour map of Horizon 1 was produced by integrating the seismic data with data obtained from outcrops, mine workings and drillhole information, (Fig. 4; LaPierre, 1986a). In light of the previously known onshore geology, the seismic survey results have clearly assisted in delineating the offshore structure. By combining these two sets of data, the reflections that constitute Horizon 1 are shown to be in very close proximity to the 6 Foot coal seam in the Port Hood syncline. Therefore, these structure contours may be used to approximate the position of that seam throughout the syncline.

Port Hood Coal Resources

In the Port Hood coalfield, structural contours (Fig. 4) indicate that the Port Hood syncline plunges to the southwest at approximately 12°. This results in the 6 Foot seam reaching a mineable limit of 1200 m vertical depth at the south end of Henry Island. The north boundary is placed no farther than the most northerly workings of the Port Hood mine due to the deterioration in seam thickness as recorded in hole PH-2. The resource area encompasses 24 km^2. The areal extent of the seam underlying the 6 Foot seam in hole PH-3 is not known and is not included in tonnage calculations. A specific gravity of 1.40 g/cm^3 was used in calculating coal tonnages. Figure 8 and Table 2 outline the resource area and tonnages estimated for each category.

The measured resources area was determined by seam location, mine workings, drillhole locations and the geological nature of the field. The boundary line is 300 m from hole PH-3. The indicated resources block was determined from known points of observation and from reasonable geological projections. The boundary limit extends 600 m from hole PH-3. The inferred resources block was determined from the geological nature of the field. The outer boundary is 1200 m from hole PH-3. The speculative resources area was delineated solely on the nature of the field as determined by the offshore seismic data and is limited by the position of the -1200 m contour line.

THE ST. ROSE-CHIMNEY CORNER COALFIELD

Geological Setting

The St. Rose-Chimney Corner coalfield is situated 15 km north of Inverness (Fig. 1). Coal-bearing strata occur at two localities, St. Rose and Chimney Corner, which are separated by 3 km of faulted strata (Fig. 9). The St. Rose area consists of a small structural depression (St. Rose Basin) 2 km by 1.2 km. To the

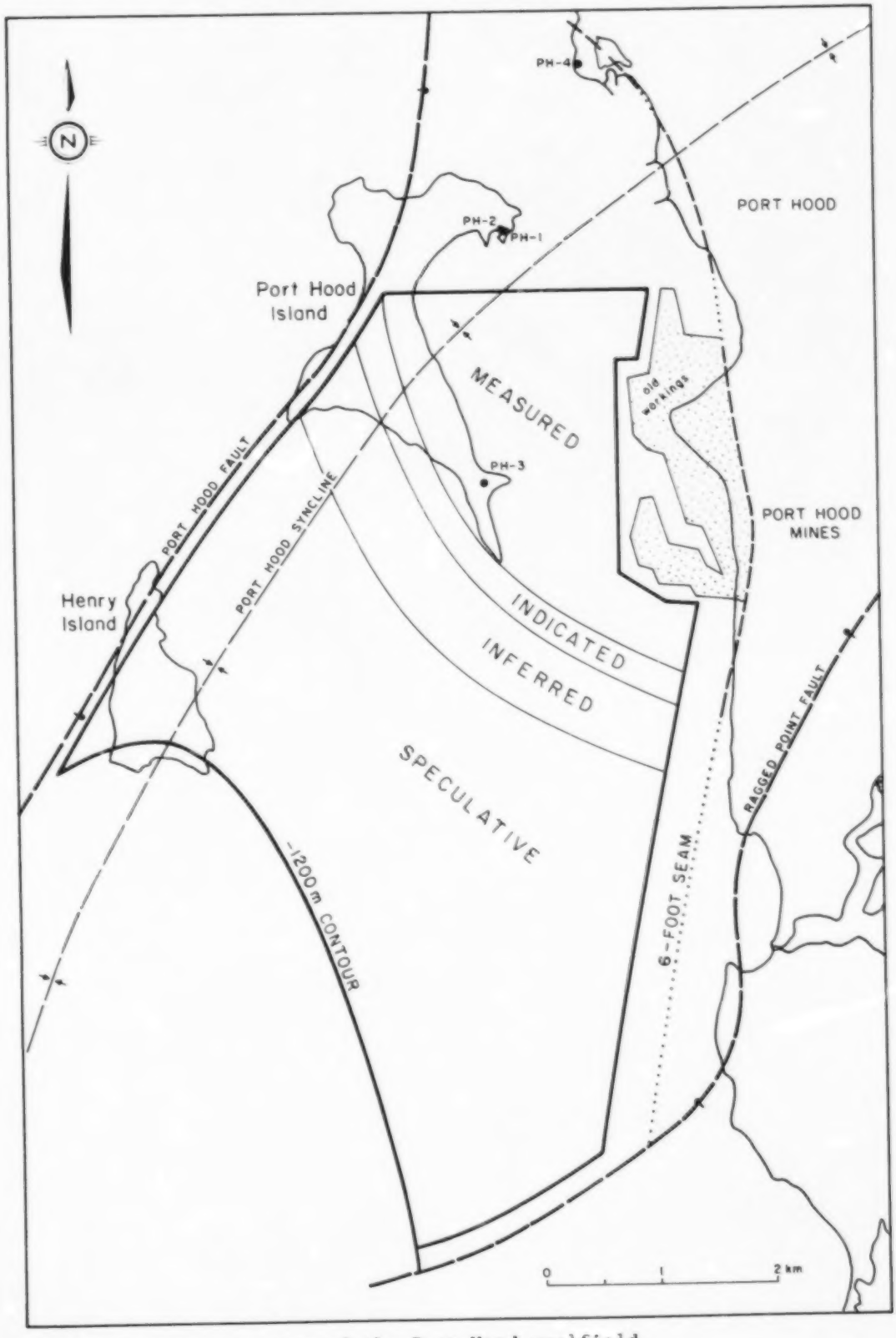


Figure 8. Coal resource areas of the Port Hood coalfield.

Table 2. Coal Resources on the 6 Foot seam, Port Hood coalfield.

Category	Area (Hectares)	Thickness (m)	Tonnage (tonnes)
Measured	486	1.8	12,247,200
Indicated	132	1.8	3,326,400
Inferred	269	1.8	6,778,800
Speculative	1601	1.8	40,345,200
Total	2488		62,697,600

north the coal-bearing strata at Chimney Corner occupy a narrow strip of coastline 2 km by 0.3 km. Except for this small land area, the coal measures at Chimney Corner are submarine.

The coal-bearing strata of the St. Rose-Chimney Corner coalfield are part of the Port Hood Formation of the Riversdale Group. The strata are folded in an ill-defined syncline that trends north-northeast (Fig. 9; St. Rose syncline, Haites, 1952). The axial region of the syncline is broken by faults and disturbed by thrusted strata of the Windsor Group. The faulting between St. Rose and Chimney Corner has offset the synclinal axis to a submarine position (Bell, 1943). On the coast at St. Rose, the Port Hood Formation is in faulted contact with Windsor and Canso Group rocks.

The Port Hood Formation at St. Rose consists of alternating thick, grey, fine grained sandstone, grey to dark grey and reddish mudstone and shale and minor intraformational conglomerate. A characteristic feature of the sandstone is the presence of abundant plant debris, shell beds and fossilized trees. The shell beds consist of several species of bivalves, the most common of which is *Curvirimula corvosa Rogers* (Vasey, 1984). Several upright fossilized trees are evident in the cliff section at Chimney Corner. The coal seams occur in a zone 150 m thick that lies in the upper part of the Port Hood Formation.

Of the five coal seams present at St. Rose, only two, the No. 2 and No. 5 seams, are of economic importance; the remainder are too thin or impure to mine. The coal seams are in a small ovate basin that is terminated on the west side by the St. Rose fault. The seams dip 30° west at the surface, gradually flatten in the axial region of the syncline and then rise slightly until they are cut off by the fault (MacNeil, 1985).

At Chimney Corner there are six seams but only two, No. 2 and No. 5, were of any economic value although records indicate that the No. 4 seam was also mined. The seams dip steeply to the west (seaward) from 30° - 40°. The coal seams are poorly exposed in the cliff section. Correlation with the coal seams of St. Rose has shown that the same sequence of seams is present at both localities (Fig. 10; Bell, 1943; Hacquebard, 1951). The seams are better developed at St. Rose than at Chimney Corner; the seams thin in a northerly direction from St. Rose (Hacquebard, 1951).

Mining History

Documented mining operations in the St. Rose-Chimney Corner coalfield began at Chimney Corner in 1867 but

Figure 9. St. Rose-Chimney Corner coalfield showing seam locations and structure contours on No. 5 seam at St. Rose.

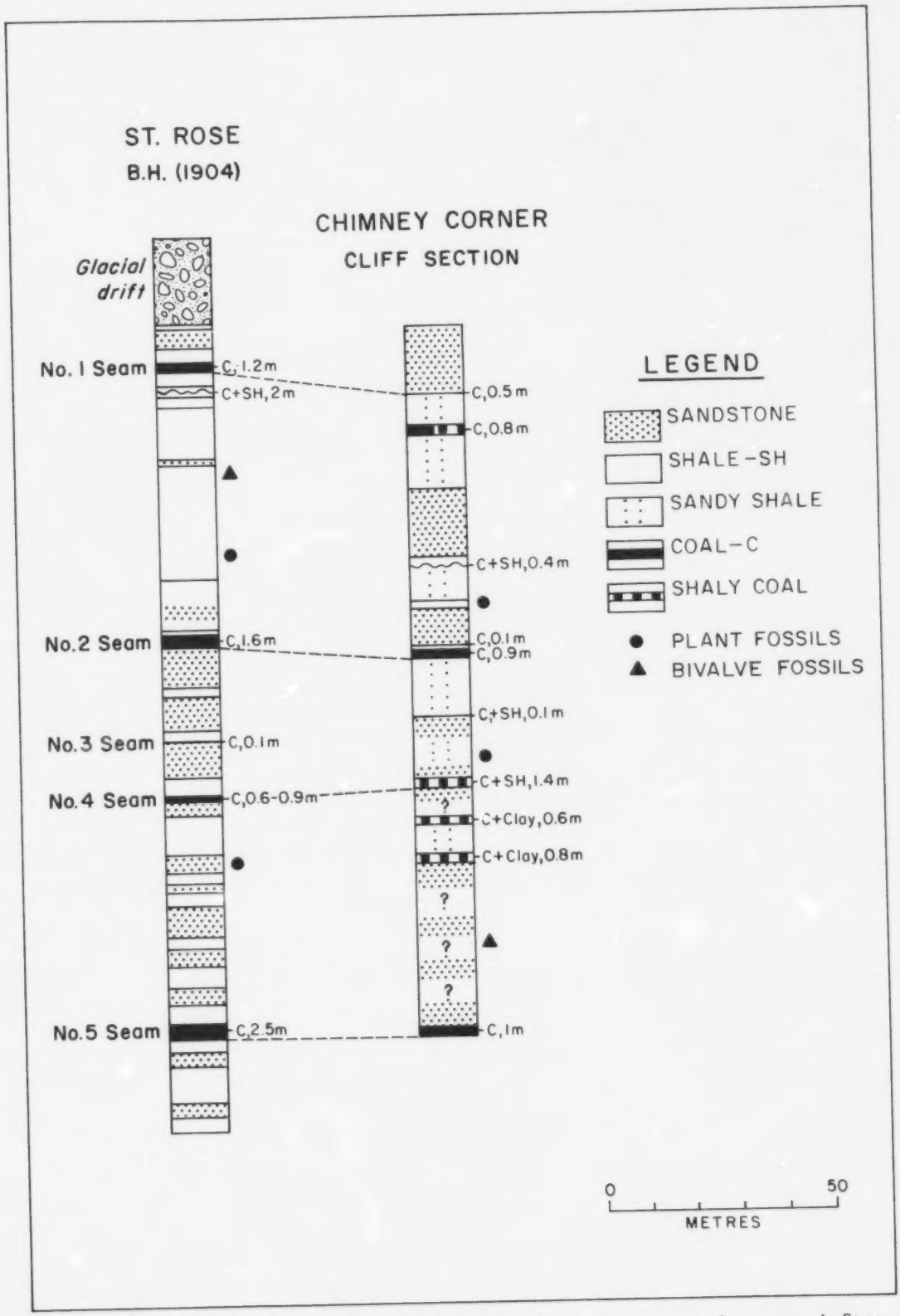


Figure 10. Correlation of the St. Rose and Chimney Corner coal seams (after Bell, 1943).

fire destroyed the mine site in 1873. Production in this period was 6697 tonnes (7328 T) from the No. 4 seam, although workings on an outlying seam are mentioned (Rutherford, 1868). No further coal production was reported until 1917 when mining of the No. 5 seam began. The mine operated until 1923 and produced 3727 tonnes (4108 T). No further coal mining was attempted at Chimney Corner.

Mining began in 1917 at St. Rose on the No. 2 seam and continued until 1951. Production in that period totalled 41 149 tonnes (45,359 T). In 1951 mining began on the No. 5 seam and continues now. Total production through 1985 was 999 103 tonnes (1,101,322 T). The St. Rose-Chimney Corner coalfield has produced 1 050 676 tonnes (1,158,171 T) of coal since the inception of mining in 1867.

The coal at St. Rose is high volatile B bituminous. Proximate analyses of the No. 5 seam at St. Rose, on an "as received" basis, indicates the following quality: moisture, 3.1%; ash, 10.0%; volatile matter, 36.5%; fixed carbon, 50.4% with sulphur at 6.6% and a calorific value on an "as received" basis of 27.9 Mj/Kg (12,008 Btu/lb) (Energy Research Laboratories, CANMET, Department of Energy, Mines and Resources, File 4273-85, 1986). At Chimney Corner the coal is high volatile C bituminous. Analyses of the No. 5 seam on an "as received" basis yields the following: moisture, 7.2%; ash, 13.2%; volatile matter, 29.9%; fixed carbon, 49.7% with sulphur at 5.6% and a calorific value of 24.7 Mj/Kg (10,623 Btu/lb). The higher rank of the St. Rose coal compared to that of the equivalent seam at Chimney Corner is considered to be due to the higher content of the maceral sclerotinite in the coal at St. Rose (Hacquebard, 1951, 1982).

Structure

The structural configuration of the St. Rose-Chimney Corner coalfield has been interpreted from geological mapping, underground mine developments and drillhole programs. The most recent work in the coalfield was in 1984 when eight holes were drilled to clarify the structural geology of the St. Rose area (MacNeil, 1985). Drilling results have significantly modified the structural interpretation of the basin, especially with respect to faulting.

In the St. Rose area the coal resource block is in the fault-bounded synclinal basin (Figs. 9 and 11). The normal St. Rose fault strikes 030°, dips 70° east and terminates the westward extensions of the coal seams. The MacRae fault, a steeply dipping normal fault, limits the coal seams to the north while the southern portion of the basin is disrupted by the West fault (Figs. 11, 12 and 13), a steeply dipping normal fault with a 12 m downthrow to the south. This net displacement effectively divides the basin into two resource areas and the combined resource area at St. Rose is 1.2 km^2.

The latest work at Chimney Corner was in 1975 when four holes were drilled onland to investigate the coals downdip from the outcrops and to test the strata underlying the No. 5 seam for additional coal seams (Gillis, 1975b). Drilling results indicate the continuity of the seams southward from Chimney Corner and have disproved the reported occurrence of seams underlying the No. 5 seam (Fig. 14). However, projection and(or) continuation of the No. 5 seam in a downdip direction (of 30 to 40° could not be established definitely as the seam was not intersected in hole CC-2 (Fig. 15). This may be due to faulting or to non-deposition or erosion (an increase in sandstone content was observed at the projected position of the No. 5 seam).

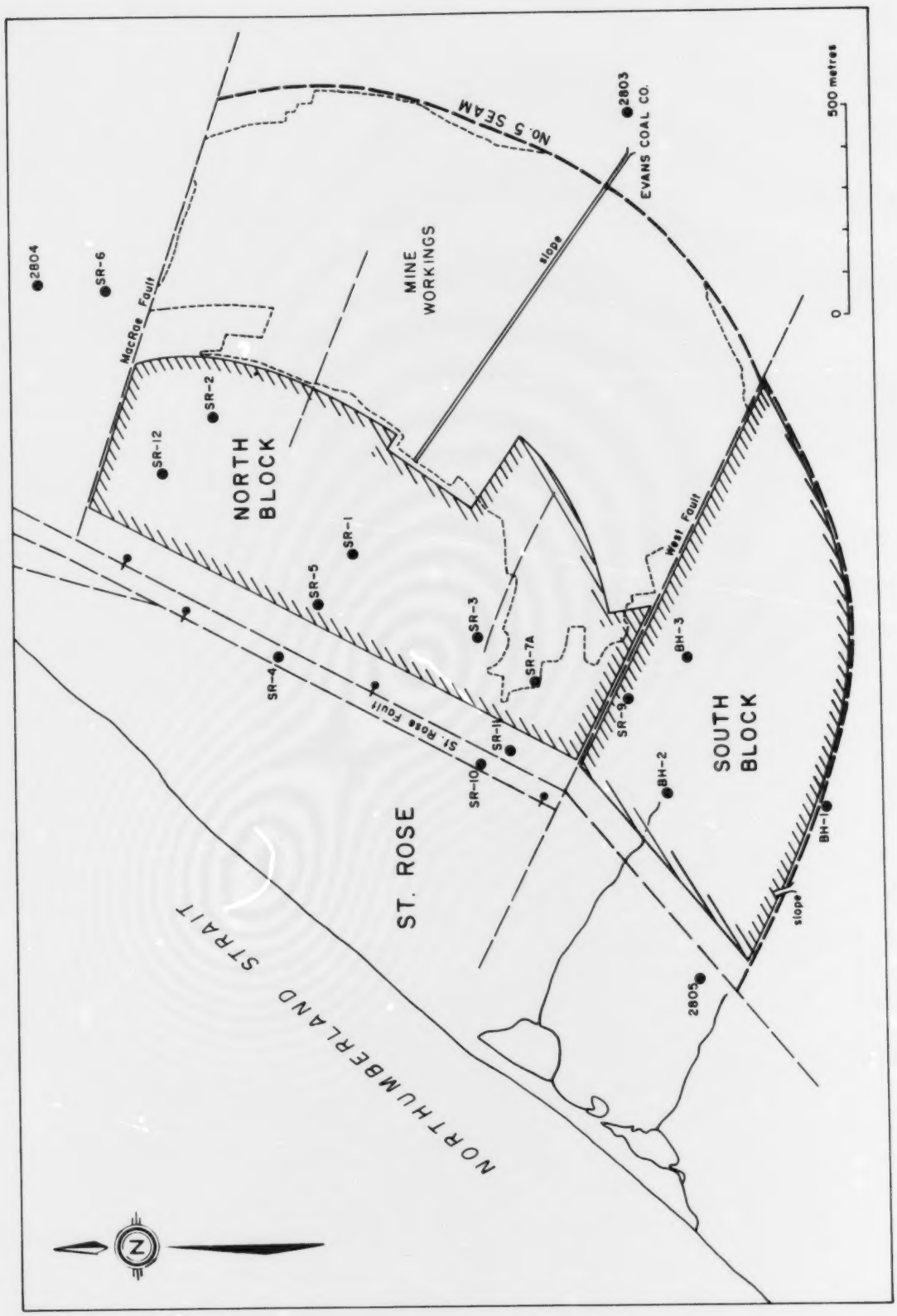


Figure 11. Coal resource areas of the No. 5 seam at St. Rose.

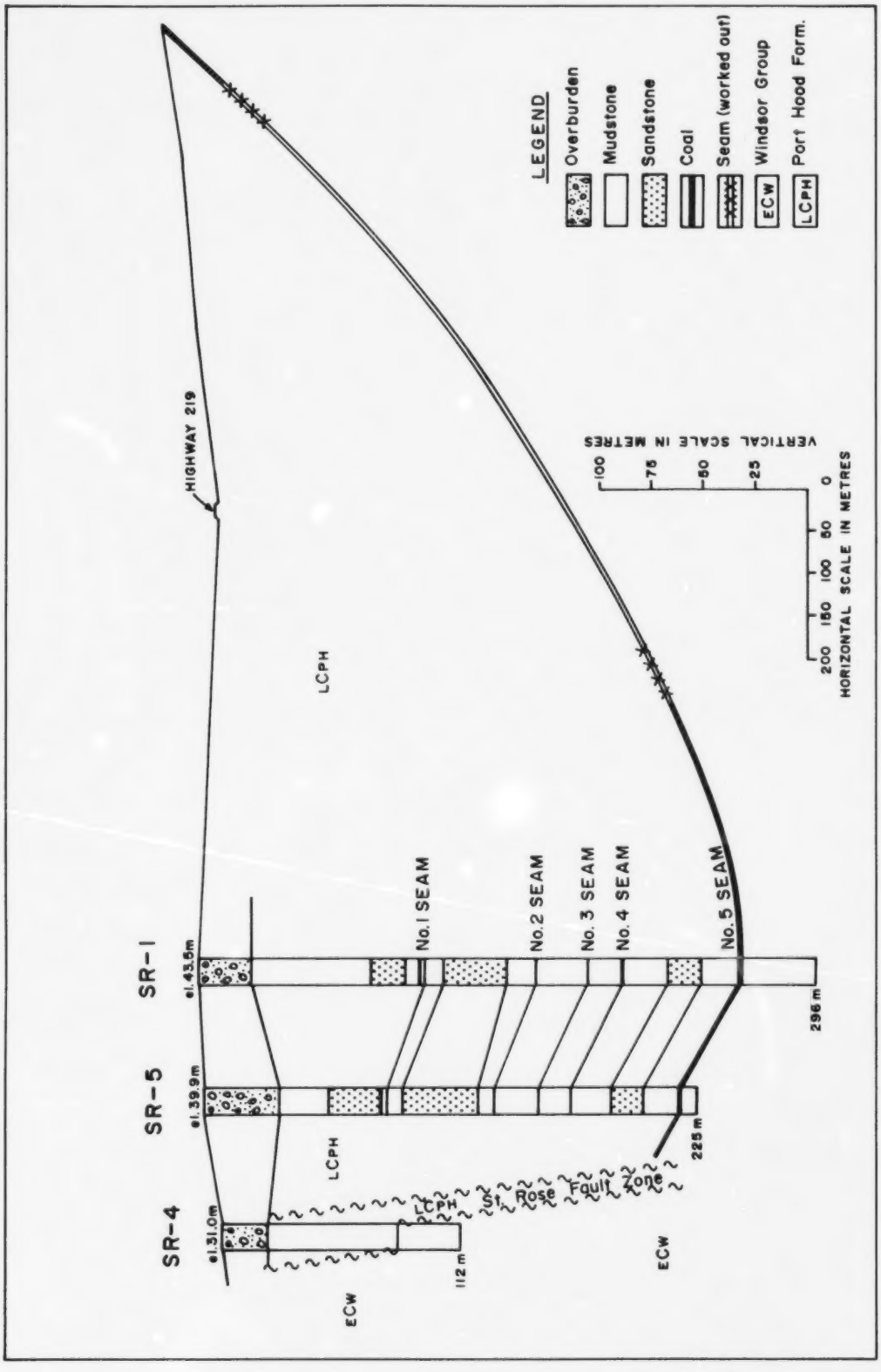


Figure 12. Cross-section through holes SR-4, SR-5 and SR-1, St. Rose (after MacNeil, 1985).

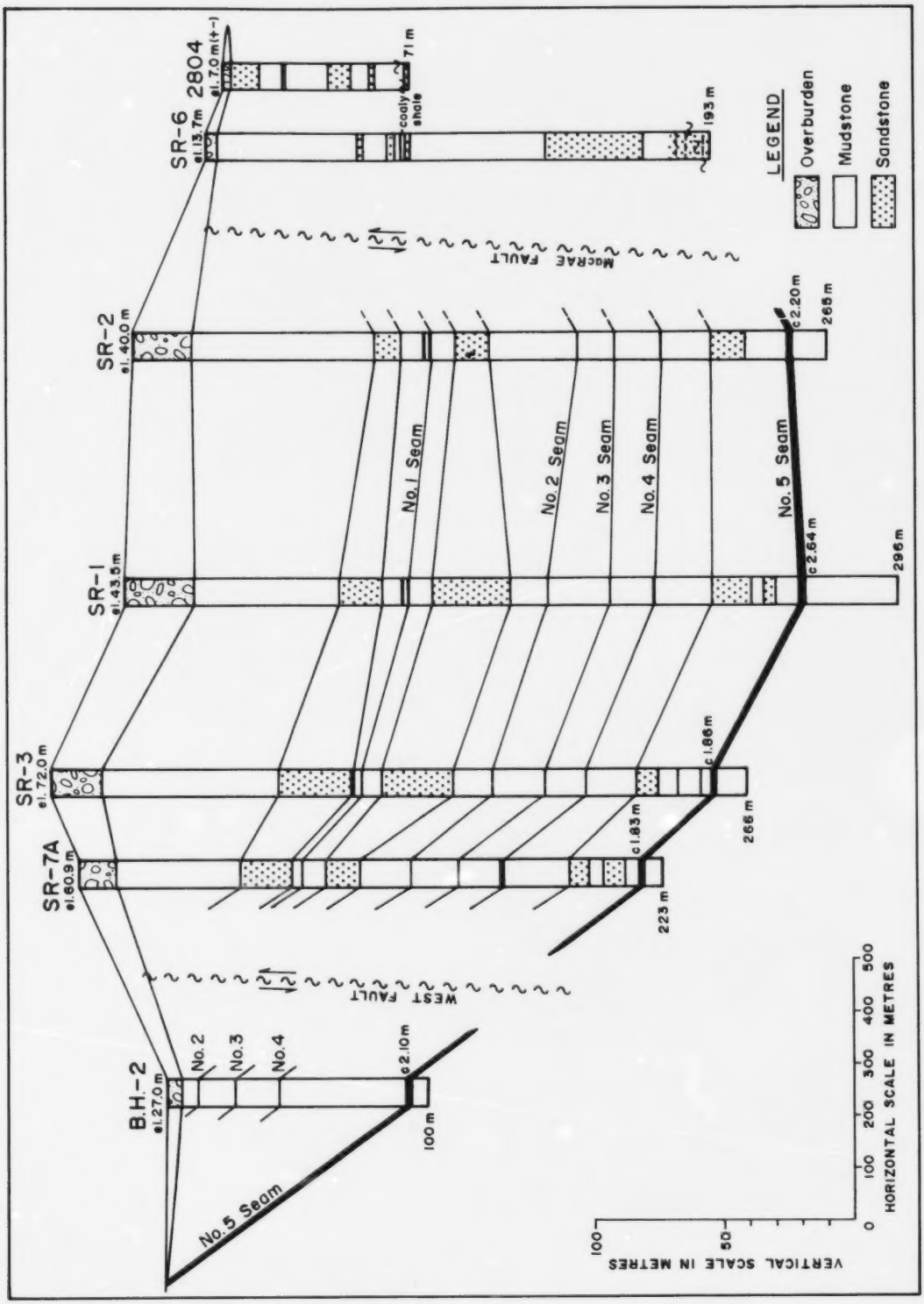


Figure 13. Cross-section through holes BH.2, SR-7A, -3, -1, -2, -6 and No. 2804, St. Rose (after MacNeil, 1985).

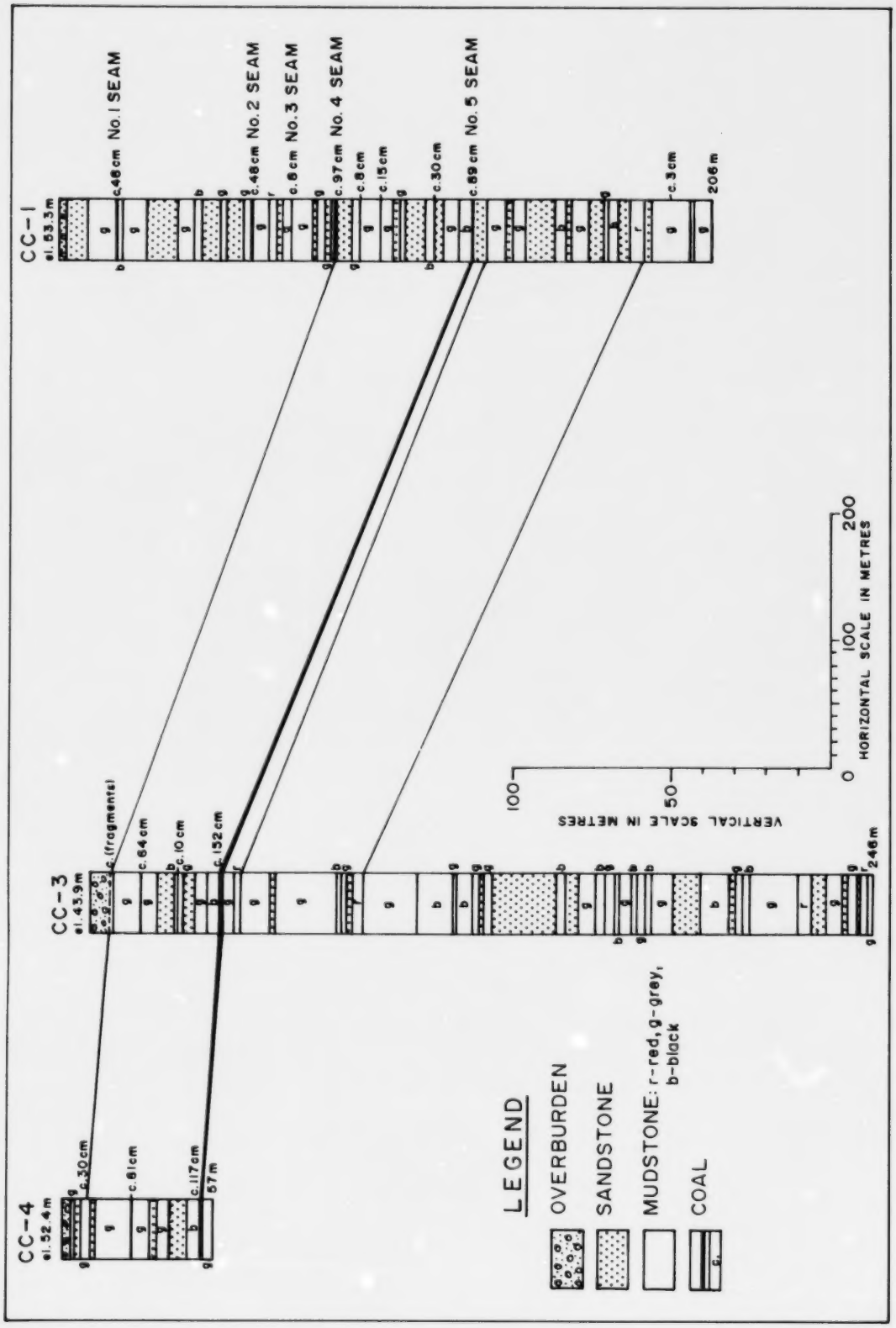


Figure 14. Cross-section through holes CC-4, 3 and 1, Chimney Corner (after Gillis, 1975b).

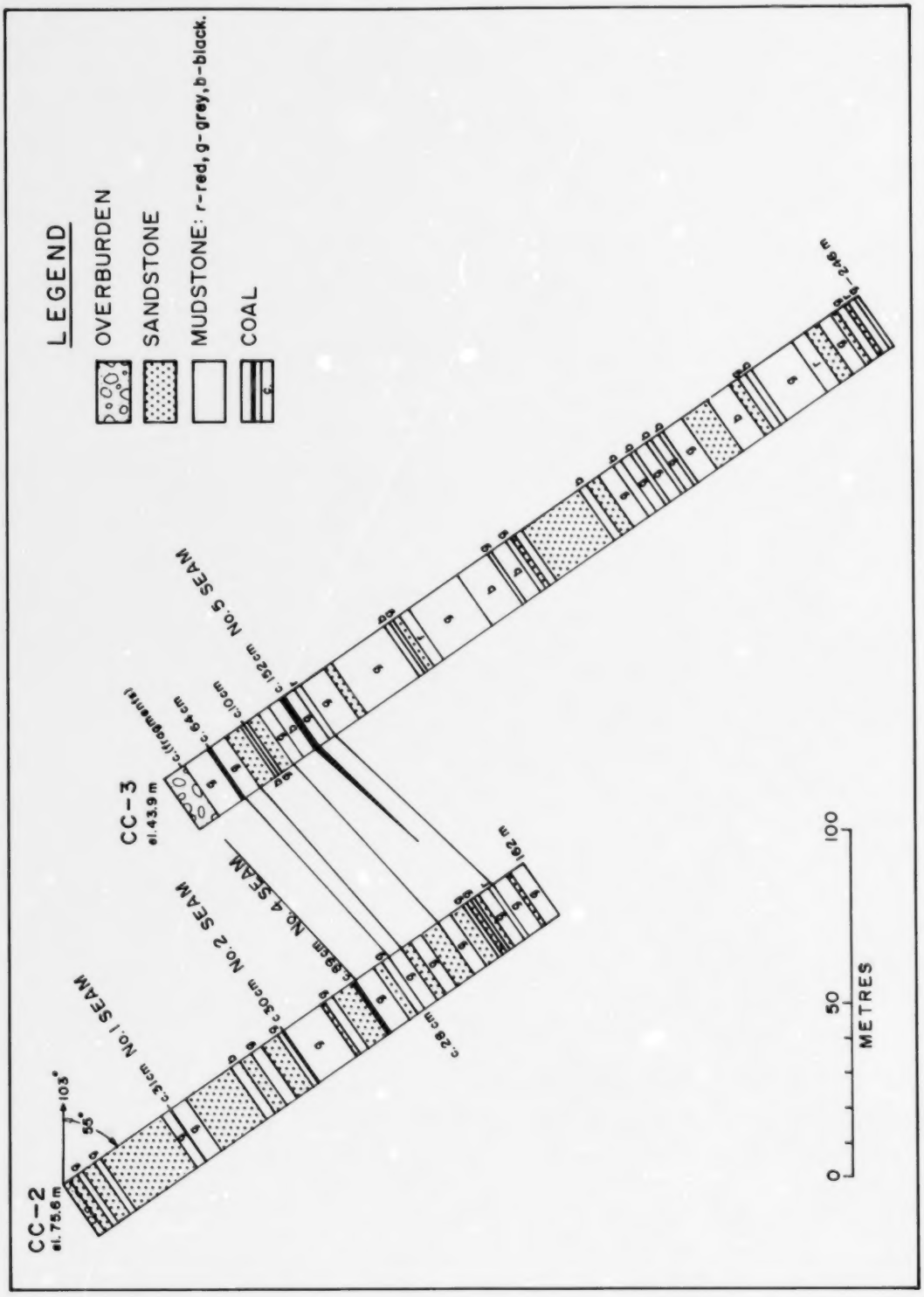


Figure 15. Cross-section between holes CC-2 and CC-3, Chimney Corner (after Gillis, 1975b).

Table 3. Coal Resources on the No. 5 seam at St. Rose

	Category	Area (Hectares)	Thickness (m)	Tonnage (tonnes)
North Block	Measured	64.8	2.23	2,019,882
South Block	Measured	52.1	1.88	1,360,181
	Total	116.9		3,390,063

St. Rose-Chimney Corner Coal Resources

It is concluded that no coal resources can be outlined at Chimney Corner for the following reasons: (1) it is believed the No. 5 seam would contain the bulk of any coal resources and its absence in hole CC-2 limits the resource area, (2) the steep dip of the strata is prohibitive to mining and (3) the extent and nature of faulting on the submarine extension of the coal seams are unknown.

Coal tonnages have been tabulated for the No. 5 seam at St. Rose (Fig. 11 and Table 3) but tonnages are not given for the No. 2 seam due to poor thickness and quality. A specific gravity of 1.40 g/cm^3 was used to calculate coal tonnages. The resource block has been divided into two areas because of the West fault. This fault would probably cause separate mining of the two resource blocks. Both resource areas are placed in the measured category.

PICTOU COALS

THE GULF OF ST. LAWRENCE CARBONIFEROUS BASIN

The Pictou Group coals of western Cape Breton Island form part of the Gulf of St. Lawrence Carboniferous Basin (Fig. 16), which is considered the largest coalfield of eastern Canada (Hacquebard, 1986). The onshore coal occurrences of this basin include the mineable deposits of Minto, Beersville, Mabou and Inverness, and the thin non-productive coals of Clifton, Shediac, McKinnon Brook, and Rivière Blanche. The position of these deposits within the Pictou Group is indicated on Figure 16 by the letters A to D, which refer to four coal-bearing spore zones also present in the Sydney coalfield.

The offshore continuity of the spore zones has been revealed by five wells drilled in the Gulf of St. Lawrence in the search for oil and gas (Fig. 17). The wells have intersected numerous coal seams, which have been assigned to the different biostratigraphic zones by their spore content (Barss *et al.*, 1979; Barss, personal communication, 1985).

Four coal zones have been recognized in the Gulf of St. Lawrence Basin: TG (Tracy-Gardiner), EB (Emery-Bouthillier), HL (Harbour-Lloyd Cove) and A (Pt. Aconi). Of these four zones, the TG and HL zones are the best developed and the most continuous. They include the 7, 8 and 15 Foot seams

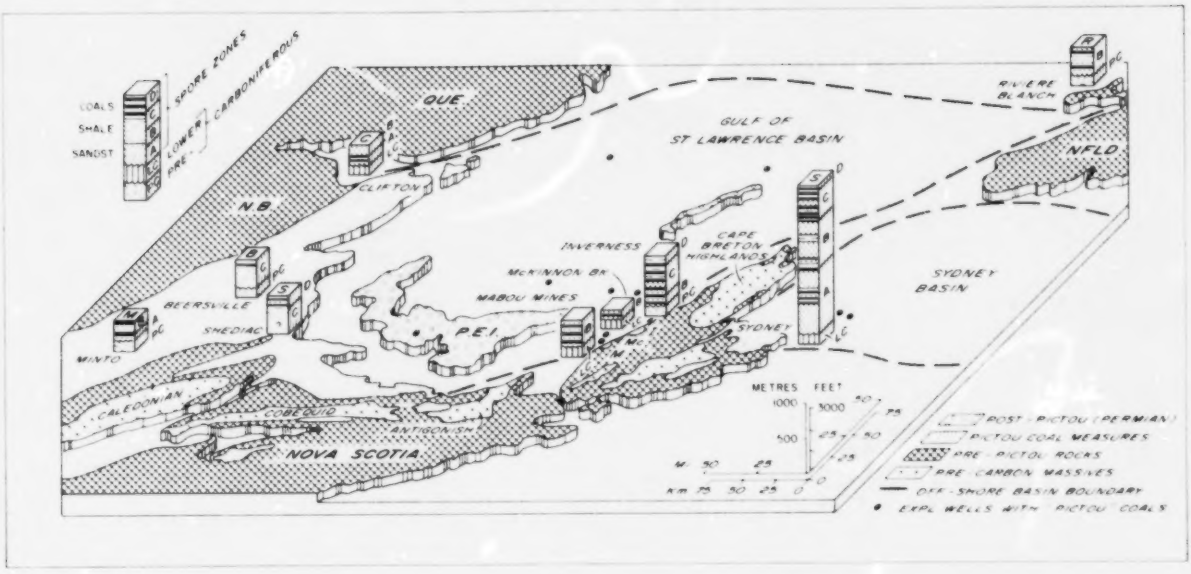


Figure 16. Onshore 'Pictou' coal occurrences of the Gulf of St. Lawrence and Syndey Carboniferous basins (after Hacquebard, 1986).

of the Mabou coalfield, and the 13 Foot and 7 Foot seams of the Inverness coalfield.

In Figure 17, borehole sections from the Gulf of St. Lawrence Basin and the Sydney Basin are aligned using the Harbour seam and its assumed correlatives as a datum level. The apparent continuity of this seam, which is the best developed and most productive coal seam of the Sydney field, is worth noting. The assumed correlation with the 7 Foot seam of Inverness indicates that it may extend northwestward for a considerable distance, possibly as far as the Bradelle well (No. 1, Fig. 17), a distance of 241 km. A very large coal basin (the Gulf of St. Lawrence Carboniferous Basin, Hacquebard, 1986) existed during Westphalian C and D time when the Pictou Group rocks were deposited. With an area of about 46 620 km^2 it surpasses the assumed size of the Sydney coalfield, which is estimated at 36 260 km^2 and thus is the largest coalfield in eastern Canada. It is regarded as one continuous field because it contains coals of mineable thickness (greater than 1.2 m) with extensive lateral continuity. Unfortunately, nearly all these coals lie at too great a depth (below 1219 m) to be mined in the submarine area, except in the nearshore areas at Mabou and Inverness.

THE MABOU COALFIELD

Onshore Coal Data

The onshore portion of the Mabou coalfield comprises two small land areas that measure only 0.25 km^2. The 366 m thick coal-bearing section within this area contains at least six seams of mineable thickness at Mabou Mines and another two seams at Finlay Point (Fig. 18; Hacquebard *et al.*, 1978). Coals outcrop in the seacliffs and lie in a westward-plunging syncline with an overturned southern limb at Coal Mine Point. There is a large anticline north of this structure and due to faulting, possibly younger seams occur in the northern limb at Finlay Point (Fig. 19).

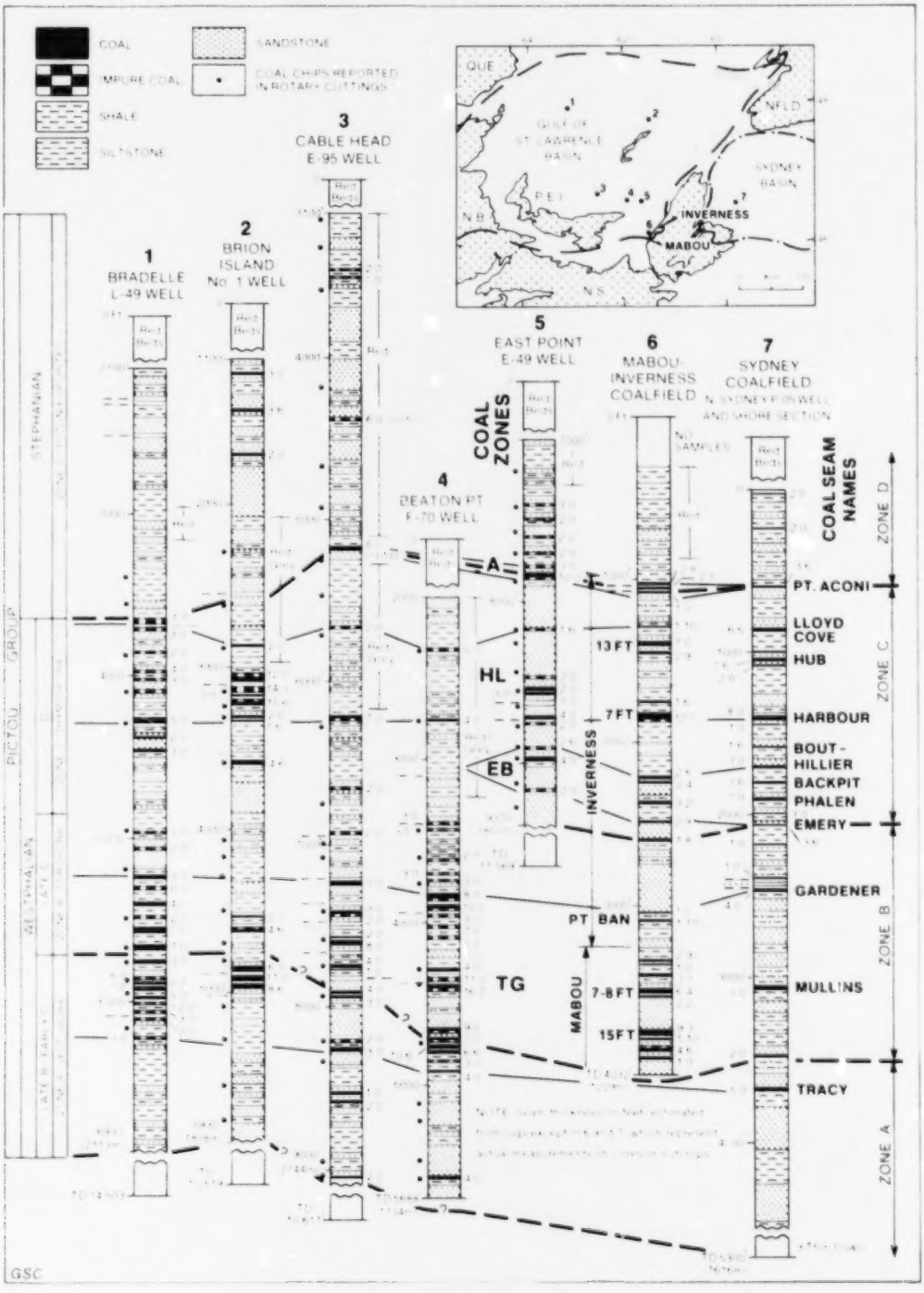


Figure 17. Distribution and correlation of the main coal-bearing strata in the Gulf of St. Lawrence and Sydney Basins (after Hacquebard, 1986).

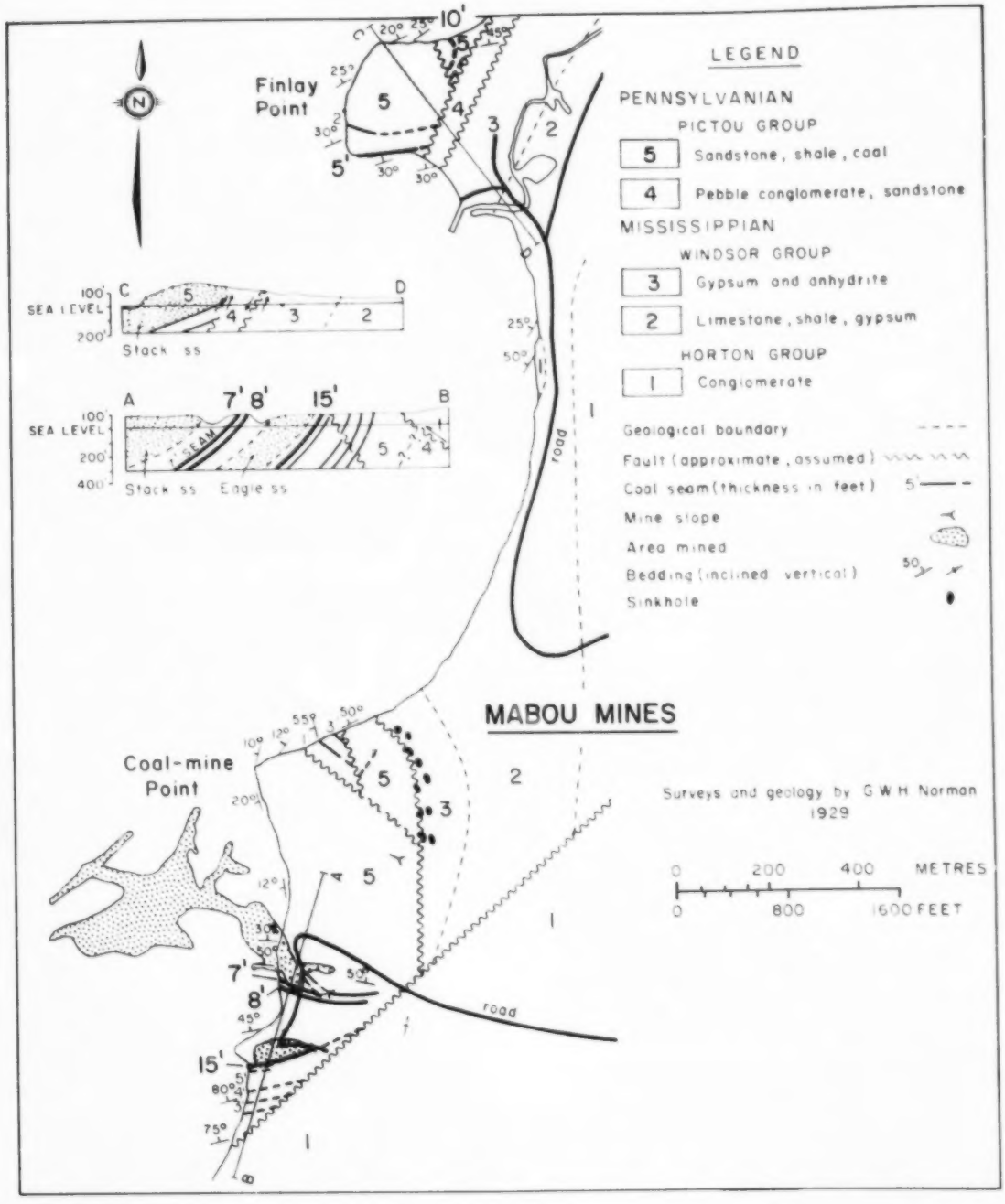


Figure 18. Geological map of Mabou coalfield (after Hacquebard *et al.*, 1978).

The principal seams at Mabou Mines are the 7 Foot, 8 Foot and 15 Foot seams. The first two have been mined in a systematic manner, with workings extending under the sea. The operation started at the turn of the century and terminated in 1909 when the mine flooded with sea water. Extensive development work was carried out, but only 54 000 tonnes of coal were

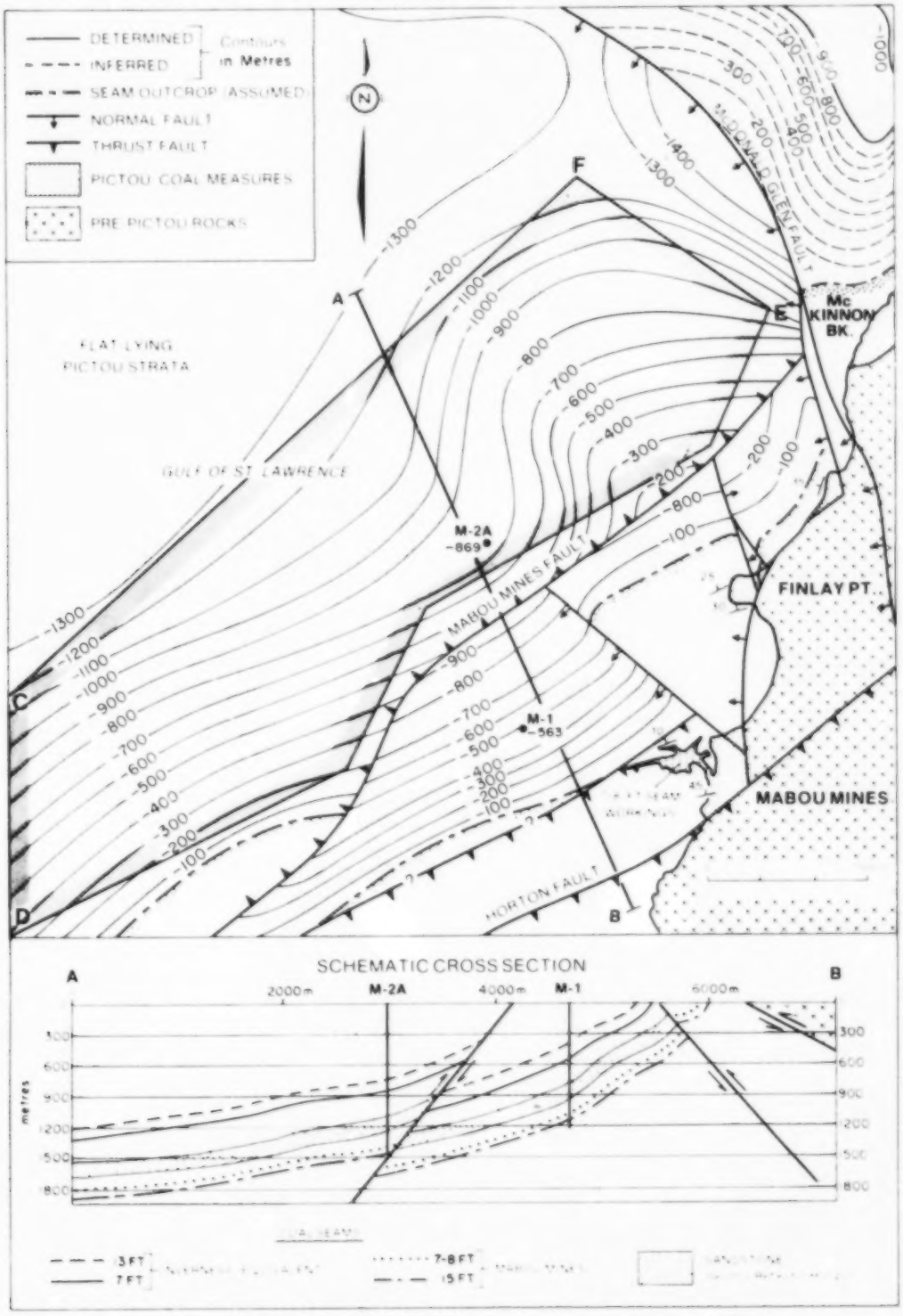


Figure 19. Structure contours of the '7 Foot Seam of Inverness Equivalent' in the Mabou Mines area (CDEF is coal resource block; after Hacquebard, 1986).

extracted. The main deep situated at about the axis of the syncline was in the 7 Foot seam, but the submarine workings and extraction were in the 8 Foot seam, which at No. 1 Level lies only 1 m below the 7 Foot seam.

Minor extraction from prospect adits, yielding an additional 8000 tonnes, was carried out between 1909 and 1951. The final operation occurred between 1961 and 1964 when 900 tonnes were taken from a nearby vertical shaft in the 15 Foot seam (Gregory, 1978).

In view of the large number of seams and their great thickness in several instances (reaching 3.66 m in the 15 Foot seam), much speculation existed about the submarine extension and reserves of this field. These were estimated at 127 million tonnes of inferred coal resources to a distance of 3.2 km from shore (Hacquebard, 1979).

Because the Mabou coals belong to spore zone B, and those of Inverness to zones B and C (Fig. 17), Hacquebard (1979) expressed the opinion that both coals may be part of a single coal basin, extending along the coast for at least 21 km. This supposition was confirmed by the results obtained from the two offshore wells drilled in 1978, which showed that the Mabou and Inverness coals form part of a continuous sequence.

The Mabou-Inverness Connection

Two boreholes, M-1 and M-2A, were put down off Mabou Mines in 1978 (Fig. 19). Borehole M-1 was located about 1.6 km from the shore and reached a depth of 1229 m; borehole M-2A was 2.4 km from shore and bottomed at 1464 m. The objective of the drilling was to determine the mining possibilities of the seams at Mabou Mines occurring within access range from the shore (not exceeding 8 km). In particular, the extent of the submarine reserves of the old submerged mine on the 7 and 8 Foot seams was considered important.

The results obtained were contrary to expectations in that the Mabou coals were encountered at too great a depth (below 1067 m) to be considered mineable. On the other hand, Inverness coals were intersected at a mineable depth of less than 914 m in offshore Mabou Mines. Although these coals were known to be younger in age, these results had not been anticipated.

The coal-bearing sequences of the two boreholes and their correlation with the shore sections at Inverness and Mabou Mines are shown in Figure 20. Spore examinations carried out by M. S. Barss (personal communications, 1978, 1985) support the remarkably close correlation that is represented. It should also be noted that the principal seams have maintained their overall thickness in the boreholes compared with the known thicknesses of coal in the onshore exposures, namely the 13 Foot and 7 Foot seams of Inverness, and the 8 Foot and 15 Foot seams of Mabou Mines.

Structure and Coal Resources at Mabou Mines

The Mabou coals, which belong to coal zone TG, lie too deep nearshore to provide sufficiently large resources for a viable mining operation. However, the 7 Foot and 13 Foot seam equivalents of the overlying Inverness section (zone HL) offer possibilities.

Figure 19 is a structure contour map of the 7 Foot seam equivalent and also relates to the structure of the 13 Foot seam equivalent, which overlies the 7 Foot seam by only 122 m (Fig. 20). The map is based on a deep-penetration seismic survey with a "Flexichoc" sound source carried out by Geomarine Associates Limited in 1978. The top of the 91-143 m thick sandstone member overlying the Port Ban seam equivalent was used as a reflector

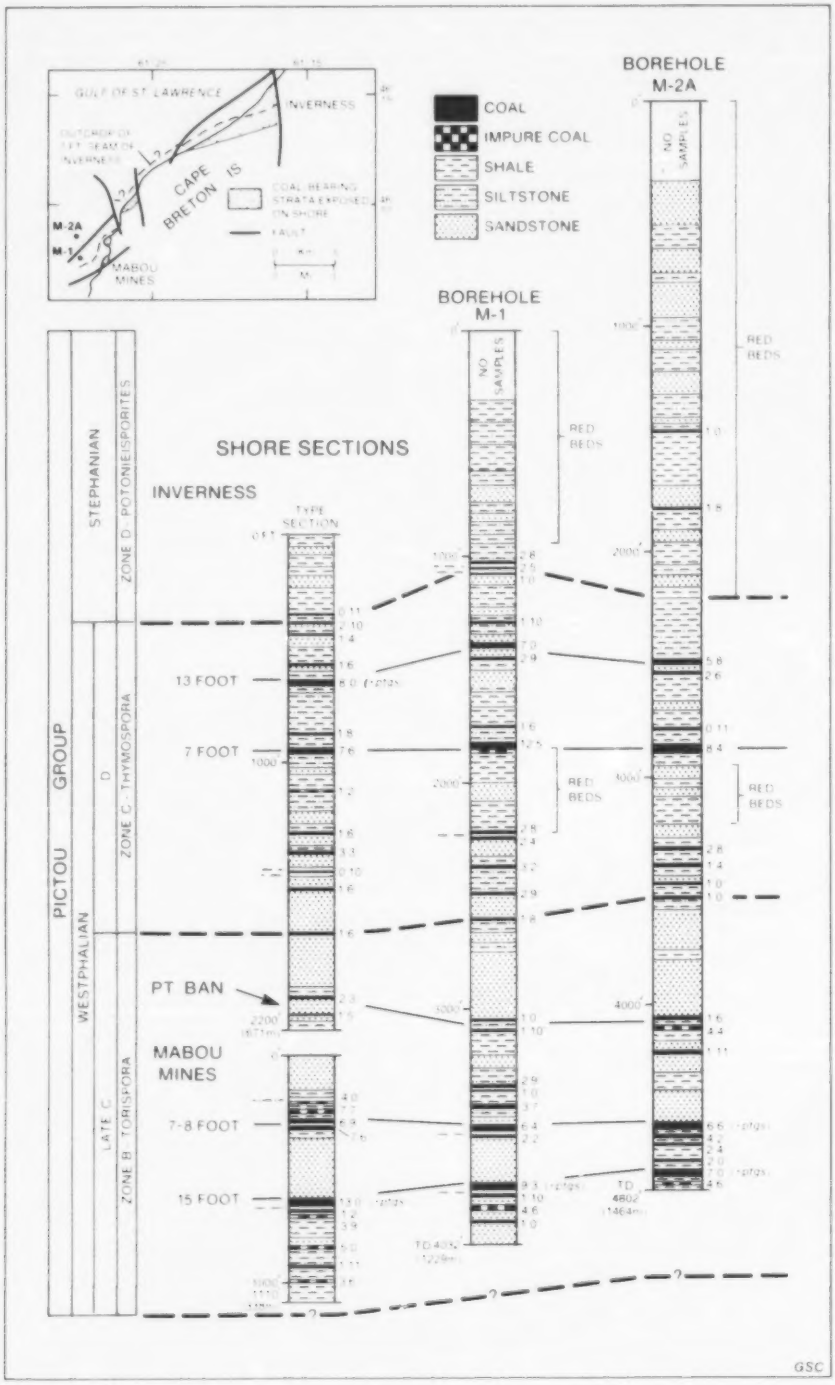


Figure 20. Correlation of the Mabou-Inverness coal-bearing sequence (after Hacquebard, 1986).

horizon. Instead of showing contours on the sandstone member (enclosure 3, Stewart and Meagher, 1978), the contours were raised by 265 m and 218 m to coincide with the position of the 7 Foot seam in boreholes M-1 and M-2A, respectively. Geological information from the onshore exposures, not shown in the Geomarine map, has been incorporated in Figure 19. The faults exposed at Mabou Mines and Finlay Point were used to plot the assumed subsea outcrop of the 7 Foot seam equivalent. Because of the presence of an anticline with associated faulting between the two areas, the Finlay Point section is considered younger than the Mabou Mines section. It is thought that the 1.5 m thick seam at Finlay Point represents the Port Ban seam, and that the 3 m thick seam on the north side of Finlay Point (map of Mabou coalfield, Norman, 1935) is the onshore outcrop of the 7 Foot seam equivalent.

The structure shown in Figure 19 consists of three subparallel southwest-trending thrust faults and a series of southeast-striking normal faults. The thrust faulting was caused by a force applied from the southeast, which pushed older Horton rocks against younger Pictou strata. This is the Horton thrust fault which dips southeast and produced the steeply dipping and partly overturned strata at the southern end of the Mabou Mines shore section. A similar fault, also dipping southeast, has been projected at the boundary of the submarine workings of the 7 and 8 Foot seams. The fault is speculative and is based on the relative depth positions of the 7 and 8 Foot seams in the old mine and in borehole M-1, which cannot readily be connected without assuming some faulting. The fault, if present at the location shown, would have terminated the mining and may have been the underlying cause for flooding of the mine at Mabou in 1909. At that time a heading off No. 1 Level was driven updip to within 91 m of the shore, where it had a cover of approximately 76 m. It was at this point that sea water entered the mine.

The Mabou Mines fault dips northwest and was defined by Stewart and Meagher (1978) from seismic records. It is a reverse fault along which the southeastern block has been pushed under the northwestern block. If it is assumed that all faulting took place simultaneously, then the force from the southeast was likely responsible for the formation of the fault. If the Mabou Mines fault occurred later, possibly in post-Permian time, pressure from the west may have been the responsible force in which case it is not a reverse fault but a thrust fault.

The Mabou Mines fault complicates access to the mineable reserves in the 7 Foot and 13 Foot seam equivalents, which lie west of the fault to a depth of 1219 m. A tunnel about 1524 m long would be required to reach this from Finlay Point. The resource area (area CDEF, Fig. 19) measures about 20 km^2. Using a thickness of 2.6 m, speculative coal resources are 69 million tonnes in the 7 Foot seam and 44 million tonnes in the 13 Foot seam, for a total of 113 million tonnes. These tonnages are speculative, being based on only one borehole in the area outlined. In light of the extensive continuation of the 7 Foot and 13 Foot seams (from Mabou Mines to Inverness over a distance of 12 km), an estimated 113 million tonnes of coal resources off Mabou Mines is not unreasonable.

Offshore Seismic Survey

Nova Scotia Department of Mines and Energy contracted Geomarine Associates Limited to collect seismic profiles in June and July 1978. The objective of the survey was to determine if the submarine coal reserves in the area were sufficiently large and accessible to warrant renewed mining.

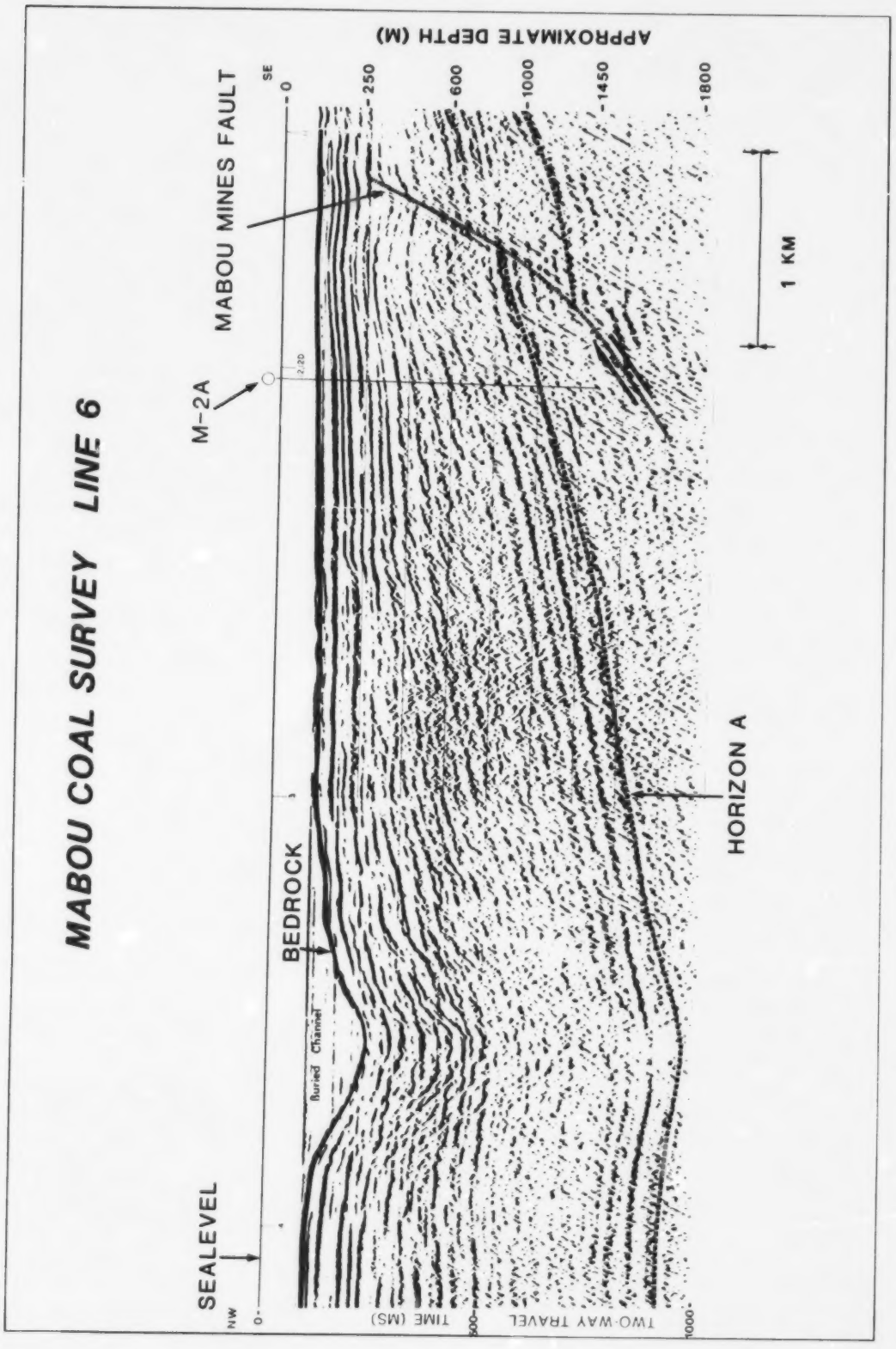


Figure 21. Mabou survey line 6.

Mabou line 6 (Figs. 2 and 21) extends from near the shore (southeast) seaward (northwest) and is used as a representative line. The important features evident on the seismic profile (Fig. 21) and the corresponding diagrammatic cross section (Fig. 22) are a shore parallel trough infilled with Quaternary sediments, a shore parallel faulted zone and a prominent reflecting event labelled Horizon A.

The uppermost reflector in Figure 21 suggests that bedrock lies near the surface and is covered by a thin veneer of Quaternary overburden except in the area of a sediment filled channel. The Mabou survey and previous surveys in the area by the Nova Scotia Research Foundation and the Geological Survey of Canada (Kranck, 1971) have shown that the channel trends southwest parallel to the coast, is infilled mainly by stratified pro-glacial sediments and reaches a maximum depth of approximately 170 m (Figs. 17 and 18; Stewart and Meagher, 1978).

Beneath this thin veneer of overburden there is a series of nearly flat-lying continuous reflectors to approximately 325 m depth. These reflector-like events are in fact caused by multiple reverberations from overlying reflectors in the upper 150-300 milliseconds (Stewart and Meagher, 1978). These multiples are often deceiving in horizontal strata but are more easily detected in the dipping strata.

On the seismic profile the structure below the multiple zone interference is relatively simple. The strata dipping seaward at a low angle are interrupted nearshore where the seismic data become less coherent (Stewart and Meagher, 1978). Initially, it was presumed that this area of poor acoustic signal response was caused by the Horton Group up-thrust block. The impression of bedrock structure as indicated by the seismic records was compared with the projections made from the known onshore geology.

Upon completion of the boreholes M-1 and M-2A, a re-interpretation of the seismic data was required since the results obtained were contrary to expectations. The top of a thick sandstone unit identified on both well logs was used as a marker to check the structure on Horizon A (Stewart and Meagher, 1978). A fault between the 2 boreholes was necessary to account for discrepancies in the logged depths of Horizon A. In borehole M-1, Horizon A is approximately 200 m above the sandstone marker unit. Figures 21 and 22 show Stewart and Meagher's (1978) interpretation of the proposed fault between M-1 and M-2A. It should be noted that the fault shown in these figures is not based on the seismic profile of line 06.

The evidence to substantiate this fault comes from tracing the fault over several other seismic lines (Fig. 2). This was done by first locating the reflector disruption on line 1 where a fault is clearly visible. A straight line extension of this fault was then completed and the proposed points of intersection on lines 2, 3, 4, 5, 6 and 11 were noted (Stewart and Meagher, 1978). Hacquebard (1986) named this fault the Mabou Mines fault (Fig. 19).

After re-evaluating the subsurface structure in light of the borehole information, a final structure contour map of Horizon A was produced by Stewart and Meagher (1978, enclosure 3). Hacquebard (1986) used the map of Horizon A as a basis to produce a structure contour map of the 7 Foot seam equivalent at Mabou. This required raising the contours by 265 m to coincide with the position of the 7 Foot seam in boreholes M-1 and M-2A.

THE INVERNESS COALFIELD

Onshore Coal Data

The Inverness coalfield lies about

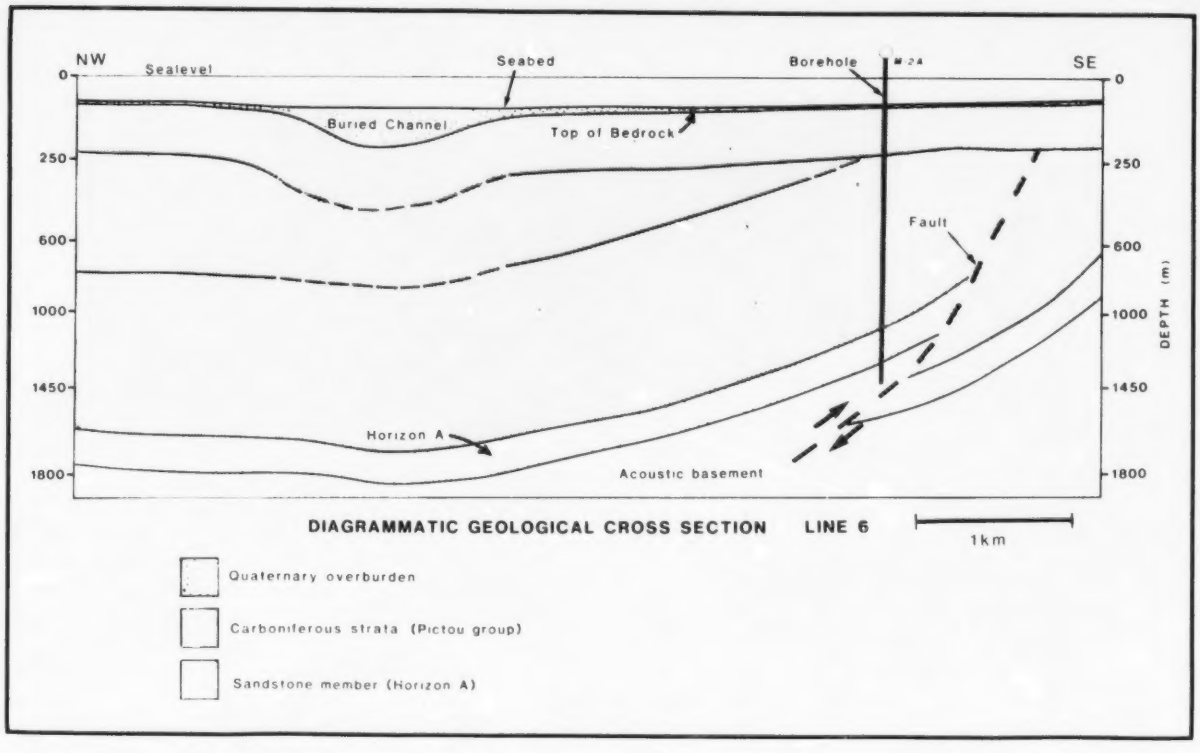


Figure 22. Diagrammatic geological cross section, line 6.

10 km north of the Mabou field and occupies an onshore area of about 9 km^2, with an undefined submarine extension. The onland section measures 732 m and contains four commercial coal seams that are from 0.9 to 4 m thick. The seams dip seaward at angles of 15° - 30°, and increase to almost 75° near the Inverness fault, which lies about 1.2 km offshore and parallels the coast (Fig. 23). The fault caused the termination of the submarine workings in the 7 and 13 Foot seams, which were the main producers of the field. Six million tonnes were mined between 1865 and 1951 and minor onshore operations continued until 1966, yielding an additional 1 million tonnes (Gregory, 1978).

The productive coal-bearing measures at Inverness are younger than those at Mabou Mines. They have been assigned to spore zone C, and their relationship to the Mabou coals was revealed by the 1978 offshore drilling at Mabou Mines.

Structure and Coal Resources at Inverness

The mineable coals of the Inverness field are represented by the 7 Foot and 13 Foot seams, which have been mined extensively and belong to coal zone HL (Fig. 17). The 7 Foot seam may be one of the most persistent coal seams of the region, not only in the Gulf of St. Lawrence Basin, but also in the Sydney coalfield, where it is correlated with the Harbour seam (Hacquebard, 1983). The 13 Foot seam is more irregular and characterized by splits and washouts.

Structure contours drawn on the 7 Foot seam (Fig. 24) also relate to the 13 Foot seam, which overlies the 7 Foot seam in this area by 91 m. The contours drawn in the mined portion of the 7 Foot seam, in the northeastern part of the coalfield, were taken from the map produced by Haites (Fig. 4, 1952),

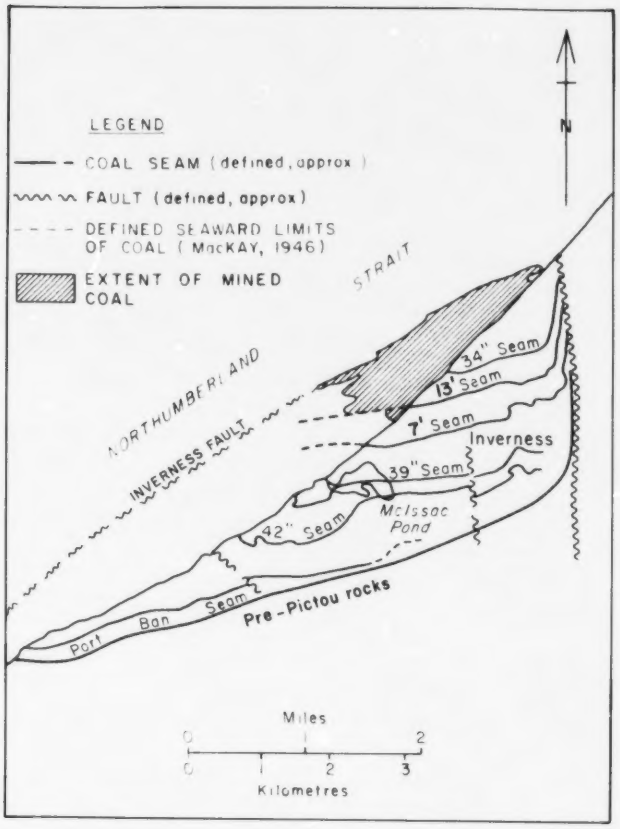


Figure 23. Geological map of Inverness coalfield (after Gregory, 1978).

who explained the nature of the Inverness fault which terminated the underground workings. The reverse fault dips eastward and was the result of a force applied from the southeast, as was the case at Mabou Mines. The fault caused the sharp increase in dip seaward from about 30° to nearly 75° at the farthest workings. A horizontal borehole drilled here (BH-884, Nova Scotia Department of Mines, 1938) started in strata dipping 65° and finished in strata dipping only 30° (MacLean, 1939). The strata with the shallower dip contained a small coal seam, which enabled Haites (Fig. 7, 1952) to extrapolate the position of the 7 Foot seam and calculate a throw of 52 m on the fault (cross-section CD, Fig. 24).

The western continuation of the Inverness fault through a fault observed in the sea cliffs 1219 m west of Port Ban, was proposed by Haites (Fig. 2 and p. 120, 1952). The connection of the two faults is speculative and critical for the evaluation of the mining possibilities in this area.

The structure contours in Figure 24 are based on the position of the Inverness fault of Haites (1952) and interpretation of the 1985 seismic survey, which will be discussed in the following section. There may be a sizeable submarine area present with substantial mining possibilities in the 7 Foot and 13 Foot seams at Inverness. This area has been divided into two

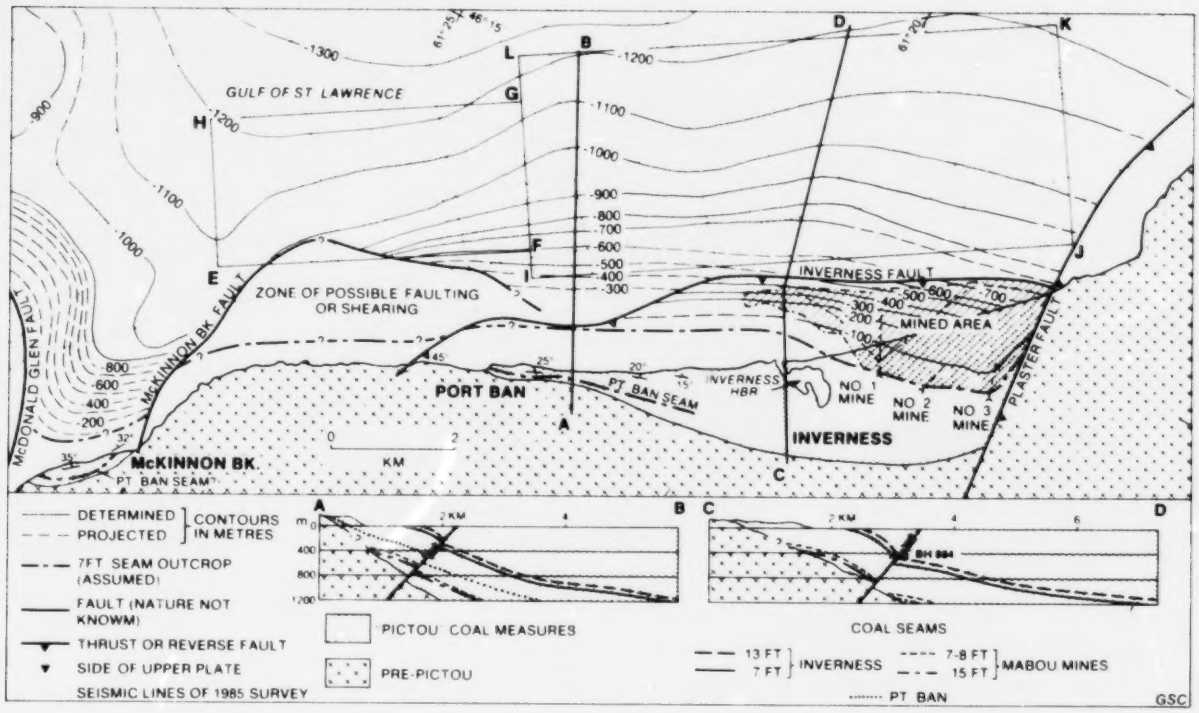


Figure 24. Structure contours on assumed 7 Foot Seam Horizon in the Inverness coalfield and adjacent area, based on 1985 seismic survey (LaPierre, 1986b; EFGH and IJKL are coal resource blocks; after Hacquebard, 1986).

blocks, EFGH and IJKL (Fig. 24). The latter has simple structure and is the more attractive, whereas the former lies north of a zone with possible faulting or shearing.

Resource calculations for block IJKL give 61 million tonnes for the 13 Foot seam (at a thickness of 1.4 m) and 94 million tonnes for the 7 Foot seam (at a thickness of 2.1 m), for a total of 155 million tonnes. In block EFGH the resources are 23 million tonnes for the 13 Foot seam and 36 million tonnes for the 7 Foot seam, for a total of 59 million tonnes. The total of the inferred coal resources of the two blocks is 214 million tonnes, to a mining depth of 1200 m.

Access to the offshore reserve requires a rock tunnel, which could be considered at Port Ban because it lies opposite the centre of the area. Along section A-B of Figure 24 a 1219 m long tunnel would be required to enter the reserve on the seaward side of the Inverness fault.

The reserve calculations are speculative. They are supported by the structural setting interpreted from the seismic study and the seam continuity of the 13 Foot and 7 Foot seams into the Gulf of St. Lawrence Coal Basin. Additional information is required and an offshore coal drilling program is considered essential for further definition of the coal resources.

Offshore Seismic Survey

In 1985, seismic data were gathered in the offshore area of

Inverness. Lines were run in a grid pattern similar to the 1978 survey (Fig. 2) to ensure consistent interpretation. The survey was designed to gather regional structure information and to identify the position and extent of the nearshore Inverness fault.

Seismic line B-04 (Fig. 2) is used as a representative example. The most important features evident on the seismic profile (Fig. 25a) are Horizons 1, 2, 3, 4, the Inverness fault and a sediment-filled seabottom channel (Fig. 25b).

Horizon 4 represents the base of the Quaternary overburden which is composed mainly of muddy sand and gravel (Kranck, 1971). The average thickness of sediments is less than 5 m but a deeper shore-parallel infilled trough in the northwest is visible. This trough is one of five channels observed on the seismic data and it has a maximum depth of approximately 100 m (LaPierre, 1986b). LaPierre (1986b) suggests that this channel may be associated with the Plaster Fault and(or) seaward extension of the Broad Cove River channel.

Horizon 3 is the shallowest reflector within the Carboniferous strata. It increases in depth from less than 100 m nearshore to greater than 1100 m near the northwest part of the survey line (LaPierre, 1986b). LaPierre (1986b) suggests that this reflector represents a gradation from coarse- to fine-grained strata separating the overlying Broad Cove Formation from the upper Inverness Formation.

Horizon 2 is more continuous, has a greater amplitude than Horizon 3 and is approximately 375 m (220 msec) below it. The approximate depth of Horizon 2 increases from less than 250 m to over 1500 m at the end of the line, 8 km offshore (LaPierre, 1986b). The event is disrupted by the Inverness fault at the southeastern limit of the line (Fig. 25). Because only one other seismic line (B06) intersects the Inverness fault, it is difficult to project reflectors across this fault based solely on the seismic data.

The 7 Foot coal seam was displaced 52 m vertically northeast across the Inverness fault, based on information from horizontal borehole BH-884 (Nova Scotia Department of Mines, 1938). To determine the displacement of a strong marker horizon across this fault it was assumed that the coal seams must parallel seismic events on both sides of the fault (LaPierre, 1986b). Horizon 2 closely approximates the position of the 7 Foot coal seam using these assumptions. More seismic data over the Inverness fault is necessary to confirm these calculations. LaPierre (1986b) estimates that the actual depth of the 7 Foot seam may be as much as 150 m below Horizon 2. The structure on this horizon is believed to be a good approximation of the structure on this seam (Fig. 24).

Horizon 1 is the deepest correlatable event on the seismic profiles. It is approximately 320 m below Horizon 2 (LaPierre, 1986b). Due to the strong attenuation of the seismic signal at these depths (over 1800 m in the northwest) interpretation becomes much more speculative. Reflectors below this horizon become less coherent down to the acoustic basement. The acoustic basement marks the maximum depth to which useful seismic interpretations can be made. This boundary has been labelled "acoustic basement" on Figure 25 and represents rocks older than the Inverness Formation.

CONCLUSIONS AND RECOMMENDATIONS

Marine geophysical techniques have proven to be a very valuable exploration tool in the offshore areas of western Cape Breton Island, Nova Scotia. Three deep penetration seismic

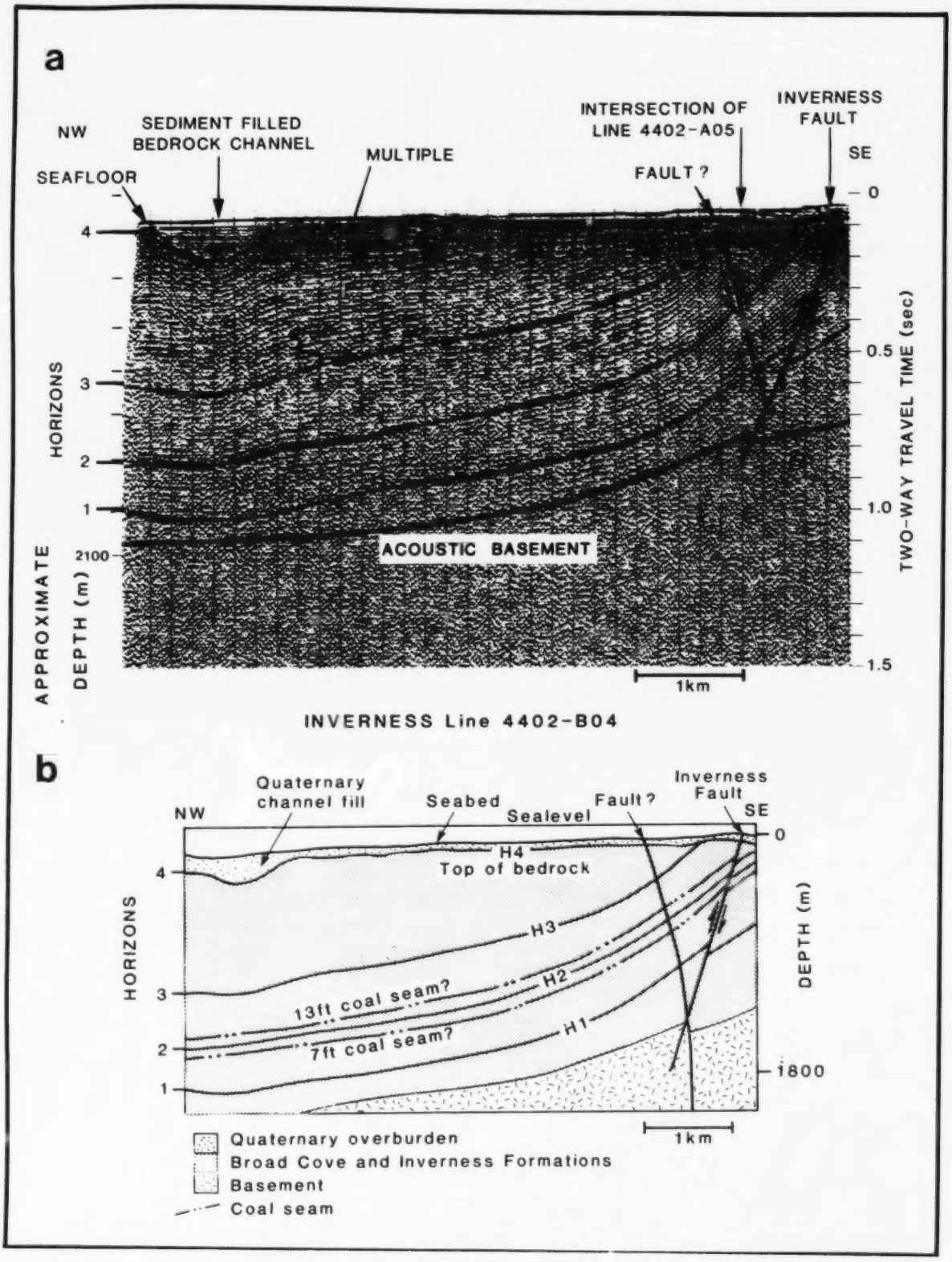


Figure 25. Inverness survey line 4402-B04 and diagrammatic geological cross section (for line position, see Figure 2).

surveys, performed since 1978, have helped to delineate the regional submarine structural geology. Over 300 km of seismic profiles have been collected. The data gathered illustrate that marine seismic methods work well in mapping coal-bearing Carboniferous strata in this area. Only a representative example from each of the 3 surveys has been discussed in this report. All data from the Mabou, Port Hood and Inverness surveys have been released as a Geological Survey of Canada Open File Report (Bromley *et al.*, 1988) consisting of 24 map-size pages showing both raw and interpreted marine seismic data collected by Nova Scotia Department of Mines and Energy and Geological Survey of Canada since 1978.

The 1978 Mabou survey established that a sandstone unit identified from borehole logs coincided with a prominent and persistent reflector referred to as Horizon A. Horizon A serves as a reliable marker with which to check the structure of locally inferred coal seams. The Port Hood survey suggests that the southeast and northwest boundaries of the Port Hood coalfield are defined by the Ragged Point and Port Hood faults respectively. Based on the offshore and onshore data, the 6 Foot coal seam is expected to occur at 1100 $\pm$ 110 m below sealevel, beneath the centre of Henry Island. The Inverness survey indicates that the structure on Horizon 2 closely approximates the position of the 7 Foot coal seam. The coal seams display an average dip of 11° northwest across the site. More data is needed in the inshore areas near Inverness to define the exact location and extent of the Inverness fault.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the following people: M. S. Barss, J. Calder, A. C. Grant, S. Hill, J. A. Hunter, D. J. MacNeil, R. Naylor and B. Sanford for assistance and advice in the preparation of the report; M. S. Barss for providing palynological data; S. J. Davis, J. DeWolfe, G. M. Grant, R. Morrison, V. Tucker and M. C. Wilson for drafting, photographic and typing services; and B. Boehner and M. Gibling for editorial review. The text was prepared with editorial assistance by Y. Brown and word processing by B. MacDonald.

Funding for this project was provided in part by the Geological Survey of Canada under the Canada-Nova Scotia Mineral Development Agreement 1984-1989.

REFERENCES

Barss, M. S., Bujak, J. P. and Williams, G. L.
1979: Palynological zonation and correlation of sixty-seven wells, eastern Canada; Geological Survey of Canada, Paper 78-24, p. 4-10.

Barss, M. S. and Hacquebard, P. A.
1967: Age and the stratigraphy of the Pictou Group in the maritime provinces as revealed by fossil spores; Geological Association of Canada, Special Paper No. 4, p. 267-282.

Bell, W. A.
1938: Fossil flora of Sydney coalfield, Nova Scotia; Geological Survey of Canada, Memoir 215, 334 p.

1943: The St. Rose-Chimney Corner coalfield, Inverness County, Nova Scotia; Geological Survey of Canada, Paper 43-14, 17 p.

1944: Carboniferous rocks and fossil flora of northern

Nova Scotia; Geological Survey of Canada Memoir 238, 277 p.

Belt, E. S.
1965: Stratigraphy and paleogeography of Mabou Group and related Middle Carboniferous facies, Nova Scotia, Canada; Geological Society of America Bulletin, v. 76, p. 777-802.

1968: Post Acadian rifts and related facies, eastern Canada; *in* Studies of Appalachian Geology: Northern and Maritime, eds. E. Zen, W. S. White, J. B. Hadley and J. B. Thompson, Jr.; John Wiley and Sons, p. 95-113.

Bielenstein, H. U., Christmas, L. P., Latour, B. A. and Tibbets, T. E.
1979: Coal resources and reserves of Canada; Department of Energy Mines and Resources Report ER79-9, 37 p.

Bradley, D. D.
1982: Subsidence in Late Paleozoic basins in the northern Appalachians; Tectonics, v. 1, no. 1, p. 107-123.

Bromley, D. S., Hill, S. and Greenly, R.
1988: Marine seismic surveys (1978-1985), offshore western Cape Breton Island, Nova Scotia; Geological Survey of Canada, Open File Report 1717.

Bromley, D. S. and Hunter, J. A. M.
1986: Reflection seismic studies: Cumberland Basin, western Cape Breton Island, Nova Scotia; *in* Tenth Annual, Open House and Review of Activities 1986; Nova Scotia Department of Mines and Energy, Information Series No. 12, p. 194-195.

Cameron, H. L.
1948: Margaree and Cheticamp Map areas, Nova Scotia; Geological Survey of Canada, Paper 48-11 (maps and mimeographed notes).

Currie, K. L.
1977: A note on post-Mississippian thrust faulting in northwestern Cape Breton Island; Canadian Journal of Earth Science, v. 14, no. 12, p. 2937-2941.

Douglas, G. V.
1945: The Port Hood coal area; Nova Scotia Department of Mines, Annual Report, p. 247-270.

Gersib, G. S. and McCabe, P. J.
1981: Continental coal-bearing sediments of the Port Hood Formation (Carboniferous), Cape Linzee, Nova Scotia, Canada; Society of Economic Paleontologists and Mineralogists, Special Publication No. 31, p. 95-108.

Gillis, K. S.
1975a: Preliminary report on the Port Hood coalfield, Inverness County, Nova Scotia; Nova Scotia Department of Mines, Open File Report No. 411, 36 p.

1975b: Preliminary report on the Chimney Corner coalfield; Nova Scotia Department of Mines, Internal Report, 14 p.

Grant, R. I.
1947: Dewatering of the No. 1 Slope, Port Hood; *in* Nova Scotia Department of Mines Annual Report, 1947, p. 179-181.

Gregory, D. J.
1978: A history of coal mining in Nova Scotia; Nova Scotia Department of Mines Information Series No. 2, 41 p.

Hacquebard, P. A.
1951: The correlation, by petrographic analysis of the No. 5 Seam, St. Rose and Chimney Corner Coalfields, Nova Scotia; Geological Survey of Canada Bulletin 19, 29 p.

1972: The Carboniferous of eastern Canada; Compte Rendu, 7th Carboniferous Congress, v. 1, p. 69-90; also *in* Benchmark Papers in Geology, no. 77, Hutchinson Ross Publishing Company, Pennsylvania, p. 44-67.

1979: A geological appraisal of the coal resources of Nova Scotia; Bulletin of Canadian Institute of Mining and Metallurgy, v. 72, no. 802, p. 76-87.

1982: Composition, origin and geology of coal; unpublished text prepared for 1982 course at Dalhousie University Department of Geology, Halifax, Nova Scotia, 147 p.

1983: Geological development and economic evaluation of the Sydney Coal Basin, Nova Scotia; Geological Survey of Canada, Paper 83-1A, p. 71-81.

1986: The Gulf of St. Lawrence Carboniferous Basin; the largest coalfield of Eastern Canada; Bulletin of Canadian Institute of Mining and Metallurgy, v. 79, no. 891, p. 67-78.

Hacquebard, P. A., Cameron, A. R., Forgeron, S. V., Potter, W. C., Shaw, W. S. and Smith, E. W.
1978: Geology of Carboniferous coal deposits in Nova Scotia; *in* Toronto '78 Field Trip Guidebook, Geological Association of Canada, p. 43-64.

Haites, T. B.
1952: Some geological aspects of the Inverness County coalfield in comparison with those of the Sydney coalfield; *in* Second Conference on the Origin and Constitution of Coal, Crystal Cliffs, Nova Scotia, p. 112-134.

Harmon, P. and Rutter, H.
1979: Seismic reflection techniques for coal exploration; presented to the First Biennial Conference of the Australian Society of Exploration Geophysicists, Adelaide, Australia.

Howie, R. D. and Barss, M. S.
1975: Upper Paleozoic rocks of

the Atlantic provinces, Gulf of St. Lawrence and Adjacent Continental Shelf; *in* Offshore Geology of Eastern Canada, eds. W. J. M. van der Linden and J. A. Wade; Geological Survey of Canada Paper 74-30, p. 35-50.

Kelley, D. G.
1967: Some aspects of Carboniferous stratigraphy and depositional history in the Atlantic provinces; Geological Association of Canada, Special Paper 4, p. 213-228.

Kranck, K.
1971: Surficial geology of the Northumberland Strait; Geological Survey of Canada, Paper 71-53, 10 p.

LaPierre, T.
1986a: Marine seismic survey, Port Hood area, Cape Breton Island, Nova Scotia; McGregor Geoscience Limited, submitted to Geological Survey of Canada, project no. 85-74.1, 42 p.

1986b: Marine seismic survey, Inverness area, Cape Breton Island, Nova Scotia; McGregor Geoscience Limited, submitted to Geological Survey of Canada, project no. 85-74.2, 47 p.

Leonard, R. B.
1951: Structure and sedimentation in the Port Hood area, Nova Scotia; unpublished M.Sc. thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, 47 p.

MacKay, A. G.
1977: Report on marine seismic profiling over a coal prospect at Mabou, Cape Breton Island; Nova Scotia Research Foundation, Report No. 3-77, 11 p.

MacLean, J. H.
1939: Geology and coal resources of the Inverness area; Annual Report of the Nova Scotia Department of Mines, 1939, Part 2, p. 114-137.

MacNeil, D. J.
1985: Geology and coal resources, St. Rose Coal Basin; Nova Scotia Department of Mines and Energy, Internal Report, 26 p.

Norman, G. W. H.
1935: Lake Ainslie Map Area, Nova Scotia; Geological Survey of Canada, Memoir 177, 103 p.

Nova Scotia Department of Mines
1938: Record of borehole no. 884; *in* Nova Scotia Department of Mines, Annual Report 1938, Part 1, p. 218-223.

Rutherford, J.
1868: Report of the Chief Commissioner of Mines for the Province of Nova Scotia, Inspector's Report, 21 p.

Stewart, J. and Meagher, L.
1978: Marine geophysical survey offshore Mabou, Cape Breton Island, Nova Scotia; Geomarine

Associates Limited, report submitted to Nova Scotia Department of Mines and Energy.

Vasey, G. M.
1984: A note on the Upper Carboniferous bivalves *Curvirimula corvosa Rogers* from Chimney Corner, Nova Scotia, Canada; Maritime Sediments and Atlantic Geology, v. 20, p. 57-60.

Webb, G. S.
1969: Paleozoic Wrench Faults in Canadian Appalachians; *in* North Atlantic Geology and Continental Drift, ed. M. Kay; American Association of Petroleum Geologists, Memoir 12, p. 754-786.